U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-269 566

Methods of Computation of Data from Exhaust Emission Surveillance Program

Ethyl Corp, Ferndale, Mich

Prepared for

National Air Pollution Control Administration, Ann Arbor, Mich Div of Motor Vehicle Pollution Control

Jun 66

GR 66-27

METHODS OF COMPUTATION OF DATA FROM EXHAUST EMISSION SURVEILLANCE PROGRAM

Prepared for the
U. S. Public Health Service
under Contract No. PH86-66-2

By
ETHYL CORPORATION
Ferndale, Michigan 48220

June 1966

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No. PB269566

4. Title and Subtitle
Methods of Computation of Data From Exhaust Emission Surveillance Program

5. Report Date
June 1966

6.

7. Author(s)
George W. Thomson

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Ethyl Corporation
1600 West Eight Mile Road
Ferndale, Michigan 48220

10. Project/Task/Work Unit No.

11. Contract/Grant No.
PH86-88-2

12. Sponsoring Organization Name and Address
U.S. Public Health Service
National Air Pollution Control Administration
Ann Arbor, Michigan 48105

13. Type of Report & Period Covered
Final Rpt.

14. 286/85

15. Supplementary Notes

16. Abstracts

This report discusses the handling of the experimental data for each visit to each city during the surveillance program. For each visit to each city, two repeat runs are made on each of 10 cars of the same make without an exhaust control device and on each of 10 different cars of the same make with an exhaust control device. Three makes of cars are tested; there are thus 120 separate runs for each visit to each city. The methods and computer programs described are used to process the separate runs and to prepare certain comparison tables.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Motor vehicles
Exhaust emissions
Surveillance
Data processing
Computer programs

17b. Identifiers/Open-Ended Terms

Emission control

17c. COSATI Field/Group

18. Availability Statement
Release Unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
77

22. Price
A05-A01

GR 66-27

METHODS OF COMPUTATION OF DATA FROM EXHAUST EMISSION SURVEILLANCE PROGRAM

by George W. Thomson

Prepared for the
U.S. Public Health Service
Under Contract No. PH 86-66-2

by
Ethyl Corporation
Ferndale, Michigan 48220

June 15, 1966

ia

TABLE OF CONTENTS

Methods of

Computation of Data From Exhaust Emission Surveillance Program

	Page
Summary	1
Contract	1
Basic Data	1
Editing and Data Deck Checking	3
Manifold Air Oxidation Devices	3
Integrator Calibration	4
Average Car Speed	4
Correction of Gas Volumes for Temperature and Pressure	4
Standard Cubic Feet Air Per Mile	5
Nitrogen Dilution Ratio	5
Equivalent Steady-State Air/Fuel Ratio	5
Air/Fuel Ratio Calculation	6
Effective Dilution Ratio and CO/CO_2 Scaled Data	6
Per Cent Air Added	7
Exhaust/Air Ratio	7
Lb/Mile of Effluents	8
Calculated Miles Per Gallon	9
Example of Calculation. Run 1H49C.	9
Run Summary	11
Refurbished Data Deck	11
Statistical Analysis Deck	12
Appendix I. Program TRAILR	
Introduction	14
Run Codes	14
Listing of Program TRAILR	16
Preload for Program TRAILR	32
Appendix II. Steady-State CO, CO_2, A/F Relations	
Introduction	34
Empirical Equations	34
Appendix III. Tables	
Introduction	37
A/F from CO	38
A/F from CO_2 (rich)	42
A/F from CO_2 (lean)	45
A/F from CO/CO_2	46
E/A from A/F	56
Correction Factor for Gas Volumes to 68°F	59
Vapor Pressure of Water	60
Appendix IV. Running The Data	
Editing Raw Data Deck	61
Run Summary Tables	62
Refurbished Data Deck and Statistical Analysis Deck	62
Comparison Tables - Effluent Variables	62
Comparison Tables - All Variables	63

SUMMARY

The methods used for the reduction of the data from the current car exhaust emission surveillance program are described. The computations are first discussed in general terms. The detailed discussion which follows is based on the IBM 1620 program TRAILR used for editing and processing the data. Newly-developed relations for the experimental concentration of CO and CO_2 as a function of A/F, the air-fuel ratio, are presented.

CONTRACT

The work described herein was carried out by Ethyl Corporation in partial fulfillment of Contract PH 86-66-2 for the Public Health Service.

BASIC DATA

This report discusses the handling of the experimental data for each visit to each city during the surveillance program. (The overall experimental design, which is described in the project contract, is not considered here.) For each visit to each city, two repeat runs are made on each of 10 cars of the same make without an exhaust control device and on each of 10 different cars of the same make with an exhaust control device. Three makes of cars (Chevrolet, Ford and Plymouth) owned by the General Services Administration (GSA) are tested. There are thus 120 separate runs for each visit to each city (plus a few on Ethyl-owned cars which are processed in the same way but not included in the comparison tables described further below). The methods and computer programs described below are used to process the separate runs and to prepare certain comparison tables.

The basic experimental information given in Table 1 is considered to be essential for each run. Together with other information (which may or may not have been obtained) it is entered on a key-punch form (Fig. 1) and eventually punched on IBM cards. Seven to 10 cards are needed for each run; these comprise the Raw Data Deck.

The IBM 1620 computer program TRAILR tests the input data for magnitudes, determines if needed data are missing, and performs calculations to provide both a standard output summarizing the run (the Run Summary), punched cards useful as input for further analysis of the results (the Statistical Analysis Deck), and a completely redone input data deck (the Refurbished Data Deck) with edited input data and newly calculated data from the program. The Refurbished Data Deck is used with a companion program CITABL to provide comparison tables for the variables.

Table 1

Essential Run Information With FORTRAN Names and Symbols

FORTRAN	names	Variable
X(1)	KRUN	5-digit alphameric run number
X(2)	KLNO	1-digit sampler number (code for laminar flow element)
X(4)	ODOM	odometer reading, miles
X(5)	ELMILE	elapsed miles
X(6)	ELMIN	elapsed minutes
X(13)	DELP1	integrator calibration pressures, delta P, in.
X(24)	DELP2	the three are usually in
X(35)	DELP3	the ratio 1: 2: 4
X(14)	CPM1	integrator calibration, counts per minute
X(25)	CPM2	at the three
X(36)	CPM3	pressures
X(15)	CTN	nitrogen integrator counts
X(26)	CTS	sampler integrator counts
X(37)	CTC	carburetor integrator counts
X(16)	GTDFN	nitrogen gas temp., deg. F
X(27)	GTDFS	sampler gas temp., deg. F
X(38)	GTDFC	carburetor gas temp., deg. F.
X(18)	DEHCIR	dilute exhaust (bag) hydrocarbon, IR, ppmc
X(19)	DEHCFI	hydrocarbon, FID, ppmc
X(20)	DECO	CO, per cent
X(21)	DECO2	CO_2, per cent
X(22)	DENOX	NOx, ppm
X(23)	DEO2	O_2, per cent
X(46)	TAMB	ambient air temperature
X(47)	PAMB	ambient barometric pressure
X(48)	HUMID	relative humidity, per cent
		license number

PUBLIC HEALTH SERVICE SURVEILLANCE

Exhaust Emission

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

ANALYST REPORT

Serial Run No.	Sampler No.	Cubic Feet per count	Odometer	Elapsed Miles	Elapsed Minutes	Calcd. MPH	Dilution Ratio	A/F Ratio	Exh./Air Ratio	Calcd. SCF/Mile Air	Calcd. SCF/Mile Exhaust	Run Code	
		.		.	.	.	.	.	.	.	.		01

Integrator ΔP	Integrator CPM	Integrator Counts	Gas Temperature Data Temp. °F.	Gas Temperature Data Corr.	HC-IR ppmc	HC-FID ppmc	CO Per Cent	CO_2 Per Cent	NOx ppm	O_2 Per Cent	Run Code	
First			Nitrogen		Dilute exhaust, observed data.							
.			.	.			.	.		.		02
Second			Sampler		Undiluted exhaust, calcd. data.							
.			.	.			.	.		.		03
Third			Carburetor		Calculated emission weight, lb. per mile.					Count Ratio		
.			.	.	.	.	.	.	.	.		04

DRIVER REPORT

License	Make	Year	Vehicle Model	Eng. Disp.	Transmission	Device?	Sampler	Driver	Analysis		
									.		05

Mo. Day Yr.	Time	City	Amb. Temp.	Atm. Pr.	Rel. Hum.	Pavement	Traffic	Owner		
/ /	.									06

Up to 5 comment cards can follow. Col. 80 9 in last card.

Prior 200 Mile Service

			0
			0
			0
			0
			0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

ECD-1203 corrected

Fig. 1 KEY PUNCH FORM

EDITING AND DATA DECK CHECKING

Computer program TRAILR has two functions. editing the Raw Data Deck and processing the data. In the Edit Mode, with Program Switch 1 ON, the Raw Data Deck cards are scanned to detect missing data, cards out of order, and data outside reasonable magnitude limits, but there is no punched output. After all of these errors are corrected the cards are edited again since some errors may not show up during the first pass. If Program Switch 2 is OFF, there is a computer pause to permit correction and reload if an error is encountered. It is usually most convenient to put Program Switch 2 ON to give continuous processing since the typed error messages provide an adequate record and the data cards can be corrected in a batch. The details of the card checking features are now described.

Four data cards, two required comment cards, and up to eight more comment cards are loaded in order. A check is made that the cards are in the correct order, that is, that the Col. 80 punch is successively 1, 2, 3, 4, 5 and 6, followed optionally by 7 or 8. (The 8 can be repeated.) The last comment card must have 9 in Col. 80. All cards must have the same run codes punched in Col. 71 to 78 and Col. 79 must be zero. If these conditions are violated, a card OUT OF ORDER message will be typed, and the computer will stop to allow correction and reload, if Switch 2 is ON. The run number is typed as soon as the first card is read. (Note that this is the first card following a last card with 9 in Col. 80 and, if a card is out of order, it may not be a card with 1 in Col. 80.)

Columns 71 to 78 contain the run codes described in a later section. If any of these are unreasonable, there is an error message. A similar message appears if any "essential" piece of data (Table 1) is negative or zero, or if the Sampler Numbers in Col. 7 of Card 1 and in Col. 75 of the run code do not agree.

All of the data are then checked to see if they lie between reasonable limits. If not, an error message is typed. The lower limits for nonessential data which may not have been filled in have been set at zero. If Switch 2 is ON, the calculations are carried out even if some of the values do not pass the magnitude tests.

It is possible that some errors may go undetected at this stage and may only be discovered when the Comparison Tables are made. Note that the program TRAILR can process any number of runs since each run is handled individually; unnecessary run processing is avoided.

The Edited Data Deck is used as input to the same program TRAILR for the data processing which is now described in detail. Program Switch 1 must be ON for these calculations to be made.

MANIFOLD AIR OXIDATION DEVICES

Minor differences in calculation are needed if an AIR-INJECTION REACTOR (A. I. R.) is used as the emission control device, as in the Fords and Chevrolets. Plymouth employs a different system, their CLEAN AIR

PACKAGE (C.A.P.). In the program, no device is coded MX = 1, C.A.P. is coded MX = 2, and A.I.R. MX = 3.

INTEGRATOR CALIBRATION

It is assumed that the counts per minute value is exactly proportional to the pressure drop in inches of water for the laminar flow elements. The three calibration pressures are usually in the ratio of 1: 2: 4. If so, an average calibration at the second pressure can be obtained by averaging the three values. However, the computer program uses a least squares solution which does not require that the three pressures be in the 1: 2: 4 ratio.

$$CPM = 0.4 \quad \frac{(DELP1)(CPM1) + (DELP2)(CPM2) + (DELP3)(CPM3)}{(DELP1)^2 + (DELP2)^2 + (DELP3)^2}$$

Here DELP1, DELP2, DELP3 are the three pressure drops in inches; CPM1, CPM2, CPM3 are the corresponding counts per minute; CPM is the least squares estimate of the counts per minute at 0.4 inches pressure drop.

Each laminar flow element is identified by a number identical to the Sampler Number, which is stored as K(5). The calibration factors, CAL(I), cubic feet per minute at 0.4 inches pressure drop, are prestored for the laminar flow elements in use. The cubic feet per count, CFPCT, is calculated from

$$CFPCT = CAL(K[5])/CPM$$

AVERAGE CAR SPEED

The average miles per hour, CMPH, is obtained from the elapsed mileage and the elapsed time in minutes.

$$CMPH = 60 \cdot ELMILE/ELMIN$$

CORRECTION OF GAS VOLUMES FOR TEMPERATURE AND PRESSURE

The correction terms to correct gas flows (as counts) to a standard temperature of 68°F (20°C) allow for both density and viscosity terms. The multiplier is equal to

$$(528/(460 + TEMP))^{1.8}$$

where the 0.8 of the 1.8 is a viscosity correction factor, (See, e.g. J. H. Perry, ed., Chemical Engineers' Handbook, 3rd edit., page 370, 1950).

The counts are also corrected for pressure giving values as dry gas at 1 atm. pressure. The vapor pressure of water is taken to be

$$\log P = 6.7671830 - 3213.24552/(t + 395.8)$$

for t = 32 to 122°F, where P is in inches of mercury. This equation is based on our own evaluation of the experimental data (G. W. Thomson, Ethyl Corp. Report LTD 50-32 and subsequent investigations). Extrapolation below 32°F leads to a small error which is negligible as far as the pressure correction is concerned. The multiplying factor for this correction is

$$PCORR = (PAMB - 0.01(HUMID)(PWAT))/29.92126$$

where PAMB is the ambient barometric pressure, HUMID is the relative humidity, per cent, and PWAT is the vapor pressure of water.

The observed counts for the nitrogen, sampler and carburetor air are designated CTN, CTS and CTC. The corresponding corrected values are CCTN, CCTS and CCTC.

The sampler to carburetor count ratio, CTS/CTC, is expected to be close to unity. Its value is termed RATIO, equivalent to X(45).

STANDARD CUBIC FEET AIR PER MILE

The amount of air per mile is obtained from the carburetor counts (CCTC), the cubic feet per count (CFPCT) and the mileage (ELMILE):

$$SCFAIR = (CCTC)(CFPCT)/ELMILE$$

Conversion to the amount of exhaust per mile requires a factor which depends on the air-fuel ratio, which is discussed in a later section.

NITROGEN DILUTION RATIO

The Nitrogen Dilution Ratio is equal to one plus the ratio of the nitrogen counts to the sampler counts, both temperature and pressure corrected. Usually it is between 3.0 and 4.0, averaging about 3.3. If we assume no air-leakage into the system between the sampling bag and the tailpipe, then the Nitrogen Dilution Ratio (designated DILRAT in the program) can be used as a scale-up factor to convert the sampling bag data to undiluted tailpipe exhaust conditions. Data scaled up in this way are termed

N_2 SCALED DATA

The label in the Comparison Tables is

DATA SCALED BY DILUTION RATIO FROM NITROGEN COUNTS

It is obvious that the effective dilution ratio will be larger than DILRAT if there is air leakage into the bag from any source.

EQUIVALENT STEADY-STATE AIR/FUEL RATIO

The air/fuel ratio (A/F) varies over a wide range in the course of the eight-mile test run. The exhaust sample can be considered a composite of a

equation is based
son, Ethyl Corp.
ation below 32°F
sure correction is

2126

s the relative
er.

rburetor air are
ed values are CCTN,

expected to be close

retor counts (CCTC),
:

tor which depends

tio of the nitrogen
e corrected.
we assume no
e tailpipe, then
am) can be used
iluted tailpipe

ITROGEN COUNTS

ger than DILRAT if

ie course of the
a composite of a

very large number of steady-state exhaust compositions each a an A/F. There is no logical reason to believe that the correc (which we have no way of knowing) should correspond to a stea calculated from the overall exhaust gas composition. However tion appears to be a good one, perhaps because of compensatin an example, suppose that a car was operating 30 per cent of t A/F = 14 (cruise conditions), 40 per cent at A/F = 12 (full-thr tion), 20 per cent at A/F = 16 (deceleration), and 10 per cent a The steady-state percentages of CO and CO_2 are given below.

Per cent	A/F	CO
30	14	1.37
40	12	6.00
20	16	0.30
10	13	3.50
Totals		3.22_1

The A/F from the overall CO is 13.11 and from the overall CC agreement within the experimental error of the CO, CO_2, A/F This case represents an extreme set of conditions; the many va in the real situation would tend to give an even greater averag various modes of operation.

AIR/FUEL RATIO CALCULATION

The equivalent steady-state A/F is estimated from the C the bag sample using a set of newly derived empirical equatio experimental steady-state data in multicylinder engines. (The presented in Appendix II.) It can be assumed safely that neithe lost or added by leakage so that the CO/CO_2 ratio in the bag sa as in the exhaust. In the computer program R is the ratio of t bag CO_2:

R = DECO/DECO2

The concentrated CO_2, CECO2, is the steady-state conditions corresponding to the ratio of the steady-state CO to the steady- to R. CECO2 is obtained from R and the A/F from CECO2.

EFFECTIVE DILUTION RATIO AND CO/CO_2 SCALED DATA

The ratio of the steady-state (concentrated) CO_2 to the ba is another type of scale-up factor. The ratio

EFFDIL = CECO2/DECO2

can be termed an Effective Dilution Ratio. Bag data scaled up termed

CO/CO_2 SCALED DATA

The label in the Comparison Tables is

DATA SCALED UP BY DILUTION RATIO FROM CO/CO_2 CALCN.

If the effective A/F, the CO and the CO_2 concentrations are in good agreement with the experimental data used as a basis for the correlation, and no air is added to the system between the combustion chamber and the sampling bag, either accidentally (air-leak) or deliberately (A.I.R. system) then the value of EFFDIL should be very close to DILRAT, from the nitrogen counts, and the value of EFFDIL should not be less than DILRAT. If this should happen, the value of EFFDIL is shown as a note on the Run Summary sheet and the computer program automatically sets EFFDIL equal to DILRAT.

The CO/CO_2 Scaled Data are an estimate of the combustion chamber effluents for the effective A/F ratio. If there is no air added, these data correspond to tailpipe-exhaust conditions. With A.I.R. devices, the concentration data for all effluents except the oxygen refer to exhaust gases from the A.I.R. unit corrected for air dilution. A limited amount of proprietary Ethyl engine data on vehicles with A.I.R. devices support this interpretation.

PER CENT AIR ADDED

The relationship between DILRAT (from the nitrogen counts), EFFDIL (from the CO/CO_2 calculation), and the amounts of nitrogen (N), sampler exhaust (S), and air (A) can be expressed schematically as follows:

$$\text{DILRAT} = 1 + N/S = (S + N)/S$$

$$\text{EFFDIL} = 1 + (N + A)/S = (S + N + A)/S$$

The percentage air, $100\,A/(A + S)$, is calculated from

$$\text{PCTAIR} = 100(\text{EFFDIL} - \text{DILRAT})/(\text{EFFDIL} - \text{DILRAT} + 1)$$

This quantity is sensitive to the values of DILRAT and EFFDIL; for DILRAT = 3.3, a 5 per cent change (EFFDIL = 3.465) corresponds to 14.2 per cent air. It is difficult to place limits corresponding to "no added air" conditions for cars with no device or C.A.P. A value of 10 per cent air on the rich side and 20 to 25 per cent on the lean side are rough estimates, which should not be taken too seriously in the light of our present knowledge.

EXHAUST/AIR RATIO

The moles exhaust per mole of air depends on the A/F ratio, the nature and amount of the hydrocarbons in the exhaust gases, and on the C/H ratio of the fuel. The computer calculations are based on two new empirical equations which are closely equivalent to values taken from a manuscript curve sheet received from Walter MacMichael of the Public Health Service on October 25, 1965. Similar curves were presented as Figure 6 of the Detroit A.P.C.A. June 1963 Meeting paper of Smith, Rose and Kruse of the Public Health Service. The basis is apparently a recalculation of the theoretical calculations of the air-fuel ratio-exhaust gas composition by D'Alleva and Lovell.

The empirical equations are for X = 8.0 to 14.6

$$Y = 2.51068 - 0.28372X + 0.01781X^2 - 0.000396X^3$$

and for X = 14.6 to 18.7

$$Y = 1.02010 - 0.013311X + 0.000500X^2$$

where X is the air-fuel ratio and Y the moles exhaust per mole carburetor air (dry basis). Calculated values from these equations, which were obtained by Chebyshev methods, are very close to the plotted curves.

LB/MILE OF EFFLUENTS

The N_2 scaled data are converted to pounds of effluent per mile using the following molecular weights.

CO	28.011	
CO_2	44.011	
NOx	46.008	(taken as NO_2)
HC	13.857	per g-atom C

The hydrocarbon effluent molecular weight of 13.857 per g-atom C is based on the extensive analysis of a sample of automotive exhaust given in the paper, Smog Chemistry Points The Way To Rational Vehicle Emission Control, by John D. Caplan of General Motors Research Laboratories presented at the August 1965 Vancouver S.A.E. meeting (Paper 650641). The individual compound results are given as ppm (vol/vol) and as mole fraction of total hydrocarbons in his Table 4. These were converted to gram-atoms C and H.

	ppm vol/vol	mole fraction of total hydrocarbons	gram-atoms C	gram-atoms H
paraffins	394	0.383	1.146	3.058
acetylenes	118	0.115	0.238	0.246
aromatics	206	0.201	1.536	1.866
olefins	310	0.304	1.041	2.082
total	1028	1.003	3.961	7.252
scaled		1.000	3.949	7.230

The hydrocarbon effluent has the empirical formula $C_{3.95}H_{7.23}$ or $CH_{1.831}$ with molecular weight equal to 54.73. (Note that the molecular weight is roughly half the value for an average gasoline.)

The multiplying factor for converting standard cubic feet of effluents to pounds is

$$\text{molecular weight}/385.318$$

where 385.318 is the SCF exhaust per lb-mole at 20°C (68°F). The values used are shown in the sample calculation.

CALCULATED MILES PER GALLON

The fuel consumption of the vehicle can be approximated by assuming that all the carbon in the fuel appears in the exhaust as carbon dioxide, carbon monoxide and a mixture of hydrocarbons (based here on FID and interpreted as $CH_{1.831}$). The fuel is taken to be equivalent to CH_2 with 61.0° API gravity (6.119 lb/gal). If the effluent emissions are expressed as lb/mile, then the miles per gallon equals

$$6.119/(1.01227(\text{HC-FID}) + 0.50077(\text{CO}) + 0.31872(CO_2))$$

where the coefficients are molecular weight ratios.

EXAMPLE OF CALCULATIONS. RUN 1H49C

Completely worked-out calculations are now presented for Run 1H49C, Chevrolet, No Device, Second Repeat Run, Car 8, Houston, First Visit. The raw data as received by the key-punch operator are shown in Fig. 2. All calculations have been carried out by hand to simulate the 8-decimal floating-point arithmetic used in the computer but the values below have been rounded to a smaller number of significant figures. Reference will be needed to the appropriate sections above at times.

Run	1H49C
Odometer	2068
Miles	8.00
Minutes	20.64
Miles/hr	23.26

Calibration of integrator.

$$\text{CPM} = 0.4 \; \frac{(0.2)(90) + (0.4)(181) + (0.8)(360)}{(0.2)^2 + (0.4)^2 + (0.8)^2} = 180.19$$

K(5)	=	3	sampler number identifies laminar element
CAL(3)	=	66.0	CFM at 0.4 in pressure drop
CFPCT	=	0.366	cubic feet/count

Gas temperature corrections.

N	93°F	$(528/553)^{1.8}$	=	0.920
S	93°F	$(528/553)^{1.8}$	=	0.920
C	95°F	$(528/555)^{1.8}$	=	0.914

Pressure corrections.

73°F	PWAT	=	0.818
	PCORR	=	29.536/29.92126 = 0.9871

PUBLIC HEALTH SERVICE SURVEILLANCE

Exhaust Emission

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

ANALYST REPORT

Serial Run No.	Sampler No.	Cubic Feet per count	Odometer	Elapsed Miles	Elapsed Minutes	Calcd. MPH	Dilution Ratio	A/F Ratio	Exh./Air Ratio	Calcd. SCF/Mile Air	Calcd. SCF/Mile Exhaust	Run Code	
1H49C	3	.	2068	8.00	20.64	23.26	3.340	12.89	.	.	.	21113082	01

Integrator	ΔP	CPM	Counts	Gas Temperature Data	Temp. °F.	Corr.	HC-IR ppmc	HC-FID ppmc	CO Per Cent	CO_2 Per Cent	NOx ppm	O_2 Per Cent	Run Code	
First	0.2	90	4000	Nitrogen	93.0	.920	645 (Dilute exhaust, observed data.)	1285	1.07	3.59	247	0.30	21113082	02
Second	0.4	181	1709	Sampler	93.0	.920	2154 (Undiluted exhaust, calcd. data.)	4272	3.57	11.99	825	1.00	21113082	03
Third	0.8	360	1732	Carburetor	95.0	.914	. (Calculated emission weight, lb. per mile.)	.	.	.	.	Count Ratio 0.937	21113082	04

DRIVER REPORT

License	Make	Year	Vehicle Model	Eng. Disp.	Transmission	Device?	Sampler	Driver	Analysis		
30895	CHEV	1966		283	AUTO	NO	3	BEANE	WAY	21113082	05

Mo Day Yr.	Time	City	Amb. Temp.	Atm. Pr.	Rel. Hum.	Pavement	Traffic	Owner		
3/11/66	3.00	H	73	30.06	64	1	3	GSA	21113082	06

Up to 5 comment cards can follow. Col. 80 9 in last card.

	Prior 200 Mile Service		
	CITY	21113082	09
			0
			0
			0
			0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

ECD-1203 corrected

Fig. 2 RAW DATA FOR RUN 1H49C

Corrected counts.

N	(4000)(0.920)(0.9871)	=	3633
S	(1709)(0.920)(0.9871)	=	1552
C	(1732)(0.914)(0.9871)	=	1563

Check on count ratio.

1709/1732 = 0.987

SCF air per mile.

SCFAIR = (1563)(0.366)/8.00 = 71.6

Nitrogen dilution ratio.

DILRAT = 1 + 3633/1552 = 3.341

N_2 scaled data.

The CO/CO_2 scaled data obtained at a later stage are also shown below.

Effluent	Bag data	N_2 Scaled data	CO/CO_2 Scaled data	
HC-IR	645	2155	2209	ppmc
HC-FID	1285	4293	4401	ppmc
CO	1.07	3.57	3.66	%
CO_2	3.59	11.99	12.29	%
NOx	247	825	846	ppm
O_2	0.30	1.00		%

Air/fuel ratio.

R = bag CO/bag CO_2 = 1.07/3.59 = 0.29805

Equivalent steady-state CO_2 = 12.295 per cent
Corresponding A/F = 12.93

Scale-up factor from CO_2
EFFDIL = 12.295/3.59 = 3.425

CO_2/CO scaled data are calculated from EFFDIL (see above) since EFFDIL (3.425) exceeds DILRAT (3.341)

Per cent air.

The value of EFFDIL is only 2.5 per cent greater than DILRAT, well within the error of fit of the basic CO, CO_2, A/F data, so that the "per cent air" is actually meaningless here; its value is

PCTAIR = (100)(0.084)/1.084 = 7.76%

E/A ratio.

At A/F = 12.93, E/A = 0.964

SCF exhaust per mile.

SCFEXH = (0.964)(71.6) = 69.0

Pounds effluents per mile.

These are obtained from the N_2 scaled concentration data and the SCF exhaust per mile.

Effluent	N_2 Scaled	Factor	lb/mile
HC-IR	2155 ppmc	0.03596×10^{-6}	0.0053
HC-FID	4293 ppmc	0.03596×10^{-6}	0.0106
CO	3.57 %	0.07270×10^{-2}	0.1792
CO_2	11.99%	0.11422×10^{-2}	0.9445
NOx	825 ppm	0.11940×10^{-6}	0.0068

Miles per gallon.

Based on the lb/mile HC-FID, CO, and CO_2 above.

CMPG = 6.119/((1.01227)(0.0106) + (0.50077)(0.1792) + (0.31872)(0.9445))
= 15.2

A similar calculation based on the CO/CO_2 scaled data gives 14.9 mpg.

RUN SUMMARY

The single-page Run Summary presents all the input data and the results of the computer calculations for each run. It is self-explanatory. Table 2 corresponds to the example. Visit means visit to that particular city. Car number is an arbitrary serial number (1 to 99) given to the car used in the tests for that city and visit. (The ninety numbers are Ethyl-owned cars.) At least one repeat or replicate run is made on each car with the same serial number. The particular run is shown below the car number on the Run Summary sheet.

REFURBISHED DATA DECK

In addition to the Run Summary output the computer generates two data decks for each run. One is the Refurbished Data Deck which is a replica of the Edited Raw Data Deck (used for the input) except that each calculated value (or blank) has been replaced by the value from the computer program. In addition, an extra card is included, coded 07 in Columns 79, 80. The make-up of this deck is illustrated in Fig. 3 which shows the deck displayed on the key punch form. The cards can be identified using Columns 79, 80. Cards 01, 02, 05, 06, and 09 are the same as in the Edited Raw Data Deck except that newly

Table 2. Run Summary

EXHAUST EMISSION SURVEILLANCE CONTRACT

SUMMARY FOR RUN 1H49C

				GAS TEMP. DEG.	CORR.		
CITY	HOUS					ODOMETER	2068
VISIT	1		COUNT			OBS. MILES	8.000
DEVICE	NONE					OBS. MINUTES	20.64
						CALC. MILES/HR	23.26
						COUNT RATIO	.987
CAR MAKE	CHEV	NITR	4000	93.	.920	AVE. COUNTS/MIN	180.2
SAMPLER	3	SAMP	1709	93.	.920	CUB. FT./COUNT	.366
CAR NUMBER	8	CARB	1732	95.	.914	SCF AIR/MILE	71.6

SECOND RUN ON THIS CAR

AMBIENT CONDITIONS		FROM NITROGEN COUNTS		FROM CO/CO2 CALCN.	
				AIR/FUEL RATIO	12.93
		DILUTION RATIO	3.341	DILUTION RATIO	3.425
TEMP.	73 F			EXH/AIR RATIO	.964
PRESSURE	30.06 IN.			SCF EXH/MILE	69.0
HUMIDITY	64 PCT	MILES/GALLON	15.2	MILES/GALLON	14.9

EFFLUENT	DILUTE EXHAUST	....NITROGEN SCALED.... UNDILUTED EXHAUST	EMISSION WT. LB/MILE	.....CO/CO2 SCALED..... UNDILUTED EXHAUST	EMISSION WT. LB/MILE
HC NDIR	645 PPMC	2155 PPMC	.0053	2209 PPMC	.0055
HC FID	1285 PPMC	4293 PPMC	.0106	4401 PPMC	.0109
NOX	247 PPM	825 PPM	.0068	846 PPM	.0070
CO	1.07 PCT	3.57 PCT	.1792	3.66 PCT	.1837
CO2	3.59 PCT	11.99 PCT	.9445	12.29 PCT	.9683
O2	.30 PCT	1.00 PCT			

```
  30895  CHEV 1966            283    AUTO   NO  3        BEANE          WAY
 3/11/66  3.00     H   73 30.06  64                1                3   GSA
                                                                       CITY
```

OUTPUT CARDS FOR FUTURE ANALYSIS OF DATA ARE LISTED BELOW...RUN 1H49C

```
 2      1      1      1      2      8     232558    2068                  2111308231
  2209   4401  36645 122948    846  10022 730000 300600 640000            2111308232
    53    106   1792   9445     68 950000 715580 689546                   2111308233
  2155   4293  35744 119926    825  10022 730000 300600 640000            2111308234
    55    109   1837   9683     70 950000 715580 689546                   2111308235

1H49C3   .366  2068  8.000  20.64 23.26 3.341 12.93  .964  71.6  69.02111308201
.2  90  4000          93.0  .920   645  1285   1.07   3.59   247  .302111308202
.4 181  1709  14.9    93.0  .920  2209  4401   3.66  12.29   846 1.002111308203
.8 360  1732          95.0  .914 .0053 .0106  .1792   .945 .0068 .9872111308204
  30895  CHEV 1966           283   AUTO  NO  3       BEANE         WAY2111308205
 3/11/66  3.00     H  73 30.06  64             1                3  GSA2111308206
         7.8  15.2               2155  4293   3.57  11.99    825 1.002111308207
                                                                  CITY2111308209
```

PUBLIC HEALTH SERVICE SURVEILLANCE

Exhaust Emission

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

ANALYST REPORT

Serial Run No.	Sampler No.	Cubic Feet per count	Odometer	Elapsed Miles	Elapsed Minutes	Calcd. MPH	Dilution Ratio	A/F Ratio	Exh./Air Ratio	Calcd. SCF/Mile Air	Calcd. SCF/Mile Exhaust	Run Code	
1H49C	3	0.366	2068	8.000	20.64	23.26	3.341	12.93	0.964	71.6	69.0	21113082	01

Integrator ΔP	Integrator CPM	Integrator Counts		Gas Temperature Data Temp. °F.	Gas Temperature Data Corr.	HC-IR ppmc	HC-FID ppmc	CO Per Cent	CO_2 Per Cent	NOx ppm	O_2 Per Cent	Run Code	
First				Nitrogen		Dilute exhaust, observed data.							
0.2	90	4000		93.0	.920	645	1285	1.07	3.59	247	0.30	21113082	02
Second			Miles/gal	Sampler			CO/CO₂ scaled — Undiluted exhaust, calcd. data.						
0.4	181	1709	14.9	93.0	.920	2209	4401	3.66	12.29	846	1.00	21113082	03
Third				Carburetor			N_2 scaled	Calculated emission weight, lb. per mile.			Count Ratio		
0.8	360	1732		95.0	.914	.0053	.0106	.1792	.945	.0068	.987	21113082	04

DRIVER REPORT

License	Make	Year	Vehicle Model	Eng. Disp.	Transmission	Device?	Sampler	Driver	Analysis		
30895	CHEV	1966		283	AUTO	NO	3	BEANE	WAY	21113082	05

Mo. Day Yr.	Time	City	Amb. Temp.	Atm. Pr.	Rel. Hum.	Pavement	Traffic	Owner		
3/11/66	3.00	H	73	30.06	64	1	3	GSA	21113082	06

Percent air	Miles/gal	N_2 scaled — Undiluted exhaust, calcd. data.							
7.3	15.2	2155	4293	3.57	11.99	825	1.00	21113082	07

Up to 5 comment cards can follow. Col. 80 9 in last card.

	Prior 200 Mile Service		
	CITY	21113082	09
			0
			0
Fig. 3 REFURBISHED DATA DECK FOR RUN 1H49C			0
			0

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

computed values are given on Card 01. Card 03 has miles/gal and concentration data on the CO/CO_2 scaled basis. Card 07 has the same information on the N_2 scaled basis plus the per cent air. Card 04 has lb/mile effluents on the N_2 scaled basis.

The Refurbished Data Deck is used as the basis of further data handling. The variable Comparison Tables are prepared using this data deck as the input to the IBM 1620 Computer Program CITABL which handles data on the 120 runs on GSA vehicles for each visit to each city.

STATISTICAL ANALYSIS DECK

In addition to the Refurbished Data Deck IBM 1620 Computer Program TRAILR punches out a special deck for possible future statistical analysis. These cards are coded with 3 in Col. 79 and are identified by Columns 79, 80. All quantities are expressed as integers, data as I7, codes as I1 or I2.

Card coded 31 in Col. 79, 80

Data times 10000, I7.

- City code
- Visit code
- Device code
- Car make code
- Replicate-run code
- Car number code
- Miles per hour
- Odometer (data unscaled, I7)

Card coded 32 in Col. 79, 80, all I7

CO/CO_2 scaled data

- HC IR, ppmc
- HC FID, ppmc
- CO, per cent times 10000
- CO_2, per cent times 10000
- NOx, ppm

N_2 scaled data

- O_2, per cent times 10000

Ambient conditions times 10000

- Temperature, °F
- Barometric pressure, in.
- Relative Humidity, per cent

Card coded 33 in Col. 79, 80, all I7

N_2 scaled data
- HC IR, lb/mile
- HC FID, lb/mile
- CO, lb/mile
- CO_2, lb/mile
- NOx, lb/mile

Carburetor temperature, °F
SCF air/mile
SCF exhaust/mile

Card coded 34 in Col. 79, 80, all I7

Same as Card 32 but CO/CO_2 scaled data are replaced by N_2 scaled data.

Card coded 35 in Col. 79, 80, all I7

Same as Card 33 but N_2 scaled data are replaced by CO/CO_2 scaled data. (Note that these CO/CO_2 scaled data are the same as the N_2 scaled data for A.I.R. equipped cars.)

APPENDIX I. PROGRAM TRAILR

The FORTRAN listing of IBM 1620 Computer Program TRAILR is shown as part of this appendix. The programming language is Kingston FORTRAN II, an advanced compiler with many "FORTRAN IV" features. Ethyl Corporation is participating in the field testing of this compiler for the IBM COMMON Users Group. The program is written in mnemonic coding and is extensively annotated. Note that the majority of the variables are equivalenced to a subscripted variable X(I), where I = 2 to 61, in order to facilitate testing and error checking. Fig. 4 shows the relation between the items on the key-punch form and X(2) to X(48).

The Run Code identifies each run and is punched in Col. 71 to 78 of all data cards.

Col. 71. City

1 Minneapolis
2 Denver
3 Houston
4 Phoenix
5 Cincinnati

Col. 72. Visit

1, 2, or 3

Col. 73. Device

1 No device
2 Device (A. I. R. or C. A. P.)

Col. 74. Car Make

1 Chevrolet
2 Ford
3 Plymouth

Col. 75. Sampler Number

1 to 9
Used to identify the laminar flow element.

Col. 76, 77. Car number

1 to 10 GSA cars
90 to 99 Ethyl Cars

Col. 78. Repeat run number

Two repeat runs are chosen as repre-
senatative and are numbered 1, 2

The program provides for an initial preload of a number of program constants. These include abbreviations for city names and car names, laminar flow element calibrations, and upper and lower limits for the variables and codes.

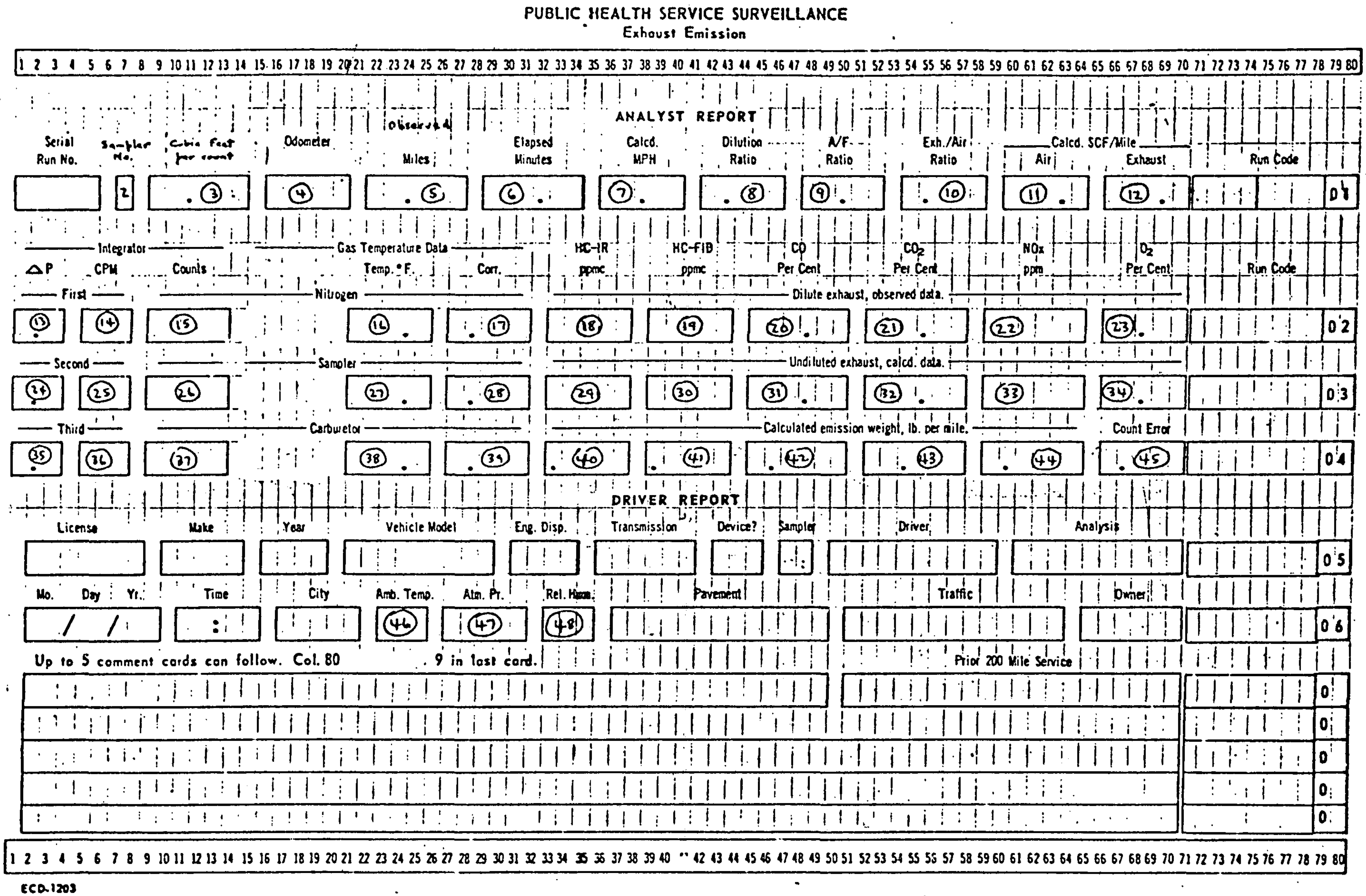

Fig. 4. NUMBERING OF X(I) STORAGES

```
*       JOB      TRAIL'...PHS DATA PROCESSOR
C
C
*       LIST
*       INDEX
C       TRAILR.....GWT.....PROJECT 90209
C       KINGSTRAN ONLY
C
C
C
C
C
C       DATA PROCESSOR FOR PHS SURVEILLANCE ...TRAILER...DATA
C
C       GEORGE W. THOMSON,  ETHYL, DETROIT
C       APRIL 6, 1966  6 PM
C
C         CHECKS THAT RUN CODES OF ALL 4 CARDS ARE ALIKE
C         CHECKS CARD ORDER
C         CHECKS THAT OBSERVED VALUES FALL IN A REASONABLE RANGE
C         RECOMPUTES ALL CALCD. VALUES
C
C       NOTE THAT SW. 1 AND 2 ARE NOT DEPENDENT ON EACH OTHER
C
C       SW. 1 ON...EDIT MODE...NO PUNCHED OUTPUT
C             OFF..PUNCHED CARD OUTPUT
C       SW. 2 CONTROLS ACTION IF AN ESSENTIAL RUN DATUM IS OUTSIDE RANGE
C                OR CARDS ARE OUT OF ORDER OR DATA OTHERWISE BAD
C             ON...NO OUTPUT...GOES TO NEXT RUN
C             OFF..PAUSE TO PERMIT CORRECTION AND RELOAD
C       SW. 2 ALSO CONTROLS ACTION IF ANY DATUM IS OUTSIDE MAGNITUDES,
C             ON...GOES AHEAD WITH OUTPUT ANYWAY
C             OFF..PAUSE TO PERMIT CORRECTION AND RELOAD
C       SKIP PUNCH OF SUMMARY IF SW. 3 IS ON
C
C       ..N2 SCALED.. MEANS DATA SCALED UP BY DILUTION RATIO
C          BASED ON THE NITROGEN COUNTS
C       ..CO/CO2 SCALED.. MEANS DATA SCALED UP BY DILUTION RATIO
C          BASED ON THE CO/CO2 CALCULATION
C
C       C=12.011, O=16, N=14.008, H=1.008       FACTOR = MOL.WT./385.318
C       HYDROCARBON....C H1.831.....13.857          0.03596
C                      C O      .....28.011          0.07270
C                      C O2     .....44.011          0.11422
C                      N O2     .....46.008          0.11940
C
C             A5                5-DIGIT RUN NUMBER...KRUN  ALPHAMERIC
C       X (2) F1.0              1-DIGIT SAMPLER NUMBER...KLNO
C       X (3) F7.3  CFPCT       CUBIC FEET PER COUNT
C       X (4) F6.0  ODOM        ODOMETER READING,  MILES
C       X (5) F7.3  ELMILE      ELAPSED MILES
C       X (6) F7.2  ELMIN       ELAPSED MINUTES
C       X (7) F6.2  CMPH        CALCD. MILES PER HOUR
C       X (8) F6.3  DILRAT      CALCD. DILUTION RATIO
C       X (9) F6.2  AF          CALCD. AIR-FUEL RATIO
C       X(10) F6.3  EARAT       CALCD. MOLAR RATIO OF EXHAUST TO AIR
```

```
C       X(11) F6.1  SCFAIR  CALCD. SCF/MILE AIR
C       X(12) F6.1  SCFEXH  CALCD. SCF/MILE EXHAUST
C
C       X(13) F3.1  DELP1   INTEGRATOR CALIBRATION PRESSURES..DELTA P..IN.
C       X(24) F3.1  DELP2      THE THREE ARE USUALLY
C       X(35) F3.1  DELP2       IN THE RATIO 1/2/4
C
C       X(14) F4.0  CPM1    INTEGRATOR CALIBRATION, COUNTS PER MIN.
C       X(25) F4.0  CPM2     AT THE THREE PRESSURES
C       X(36) F4.0  CPM3      X(13),X(24),X(35)
C
C       X(15) F6.0  CTN     NITROGEN   INTEGRATOR COUNTS
C       X(26) F6.0  CTS     SAMPLER    INTEGRATOR COUNTS
C       X(37) F6.0  CTC     CARBURETOR INTEGRATOR COUNTS
C
C       X(16) F6.1  GTDFN   NITROGEN   GAS TEMP. DEG F
C       X(27) F6.1  GTDFS   SAMPLER    GAS TEMP. DEG F
C       X(38) F6.1  GTDFC   CARBURETOR GAS TEMP. DEG F
C
C       X(17) F6.3  GTCFN   NITROGEN   GAS TEMP. CORRECTION FACTOR
C       X(28) F6.3  GTCFS   SAMPLER    GAS TEMP. CORRECTION FACTOR
C       X(39) F6.3  GTCFC   CARBURETOR GAS TEMP. CORRECTION FACTOR
C
C       X(18) F6.0  DEHCIR  DILUTE EXHAUST HYDROCARBON..IR...OBS..PPMC
C       X(19) F6.0  DEHCFI  DILUTE EXHAUST HYDROCARBON..FIA..OBS..PPMC
C       X(20) F7.2  DECO    DILUTE EXHAUST CARBON MONOXIDE...OBS..PER CENT
C       X(21) F7.2  DECO2   DILUTE EXHAUST CARBON DIOXIDE....OBS..PER CENT
C       X(22) F7.0  DENOX   DILUTE EXHAUST NITROGEN OXIDE....OBS..PPM
C       X(23) F6.2  DEO2    DILUTE EXHAUST OXYGEN............OBS..PER CENT
C
C       X(29) F6.0  UEHCIR  SAME AS X(18) - X(23)
C       X(30) F6.0  UEHCFI   BUT
C       X(31) F7.2  UECO      FOR
C       X(32) F7.2  UECO2      UNDILUTED EXHAUST
C       X(33) F7.0  UENOX       CALCULATED
C       X(34) F6.2  UEO2         SAME UNITS
C
C       X(40) F6.4  EWHCIR  SAME AS X(18) - X(22)
C       X(41) F6.4  EWHCFI   BUT CALCULATED
C       X(42) F7.4  EWCO      AS
C       X(43) F7.3  EWCO2      EMISSION WEIGHTS
C       X(44) F7.4  EWNOX       LB PER MILE
C
C       X(45) F6.3  RATIO   COUNT RATIO...SAMPLER/CARBURETOR
C
C       X(46)       TAMB    AMBIENT AIR TEMPERATURE..DEG. F
C       X(47)       PAMB    AMBIENT AIR PRESSURE..IN. HG
C       X(48)       HUMID   PER CENT RELATIVE HUMIDITY
C
C       X(50) TO X(61)      ..CO/CO2 SCALED.. VALUES    SEE EQUIVALENCES
C
C
C                   K(1)  CODE FOR CITY.  . . . . . .1,2,3,4,5
C                   K(2)  CODE FOR VISIT  . . . . . .1 TO 9
C                   K(3)  CODE FOR DEVICE . . . . . .1,2
C                   K(4)  CODE FOR CAR MAKE . . . . .1,2,3
```

```
C                    K(5)  CODE FOR SAMPLER. . . . . . .1 TO 9
C                    K(6)  CODE FOR CAR NUMBER . . . . .1 TO 99
C                    K(7)  CODE FOR REPEAT RUN . . . . .1,2
C                    K(8)  CARD SET NUMBER     . . . . .0 OR 1 ONLY
C                    K(9)  CARD NUMBER IN SET  . . . . .1 TO 9
C
      DIMENSION X(70),K(20),XLOW(70),XHIGH(70),KLOW(20),KHIGH(20)
      DIMENSION V(50)
      DIMENSION ICOMM(10)
      DIMENSION N1(5),N2(5),N3(3),N4(3)
      DIMENSION C(5),    CMAKE(10),CITY(10),CAL(9)
C
      EQUIVALENCE (X(3),CFPCT),(X(5),ELMILE)
      EQUIVALENCE (X(6),ELMIN),(X(4),ODOM)
      EQUIVALENCE (X(7),CMPH)
      EQUIVALENCE (X(8),DILRAT),(X(9),AF),(X(11),SCFAIR),(X(12),SCFEXH)
      EQUIVALENCE (X(18),DEHCIR),(X(19),DEHCFI),(X(20),DECO)
      EQUIVALENCE (X(21),DECO2), (X(22),DENOX), (X(23),DEO2)
      EQUIVALENCE (X(13),DELP1),(X(24),DELP2),(X(35),DELP3)
      EQUIVALENCE (X(14),CPM1),(X(25),CPM2),(X(36),CPM3)
      EQUIVALENCE (X(15),CTN), (X(26),CTS), (X(37),CTC)
      EQUIVALENCE  (X(16),GTDFN),(X(27),GTDFS),(X(38),GTDFC)
      EQUIVALENCE (X(17),GTCFN), (X(28),GTCFS), (X(39),GTCFC)
      EQUIVALENCE (X(29),UEHCIR),(X(30),UEHCFI),(X(31),UECO)
      EQUIVALENCE (X(32),UECO2), (X(33),UENOX), (X(34),UEO2)
      EQUIVALENCE (X(40),EWHCIR),(X(41),EWHCFI),(X(42),EWCO)
      EQUIVALENCE (X(43),EWCO2), (X(44),EWNOX), (X(10),EARAT)
      EQUIVALENCE (X(45),RATIO)
      EQUIVALENCE (X(46),TAMB),(X(47),PAMB),(X(48),HUMID)
      EQUIVALENCE (X(50),CSCFEX),(X(51),CEHCIR),(X(52),CEHCFI)
      EQUIVALENCE (X(53),CECO),(X(54),CECO2),(X(55),CENOX)
      EQUIVALENCE (X(57),CWHCIR),(X(58),CWHCFI),(X(59),CWCO)
      EQUIVALENCE (X(60),CWCO2),(X(61),CWNOX)
C
C     PRELIMINARIES
C
C
C
    1 C(1) = 0.03596E-6
      C(2) = 0.03596E-6
      C(3) = 0.07270E-2
      C(4) = 0.11422E-2
      C(5) = 0.11940E-6
      N1(1) = 3HFIR
      N1(2) = 3HSEC
      N1(3) = 3HTHI
      N1(4) = 3HFOU
      N1(5) = 3HLAT
      N2(1) = 3HST
      N2(2) = 3HOND
      N2(3) = 3HRD
      N2(4) = 3HRTH
      N2(5) = 3HER
      N3(1) = 3HNON
      N4(1) = 3HE
      N3(2) = 3HC.A
```

```
      N4(2) = 3H.P.
      N3(3) = 3HA.I
      N4(3) = 3H.P.
      ASSIGN 9001 TO ICOMM(1)
      ASSIGN 9002 TO ICOMM(2)
      ASSIGN 9003 TO ICOMM(3)
      ASSIGN 9004 TO ICOMM(4)
      ASSIGN 9005 TO ICOMM(5)
      ASSIGN 9006 TO ICOMM(6)
      ASSIGN 9007 TO ICOMM(7)
      ASSIGN 9008 TO ICOMM(8)
      ASSIGN 9009 TO ICOMM(9)
      ASSIGN 9010 TO ICOMM(10)
 9001 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9002 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9003 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9004 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9005 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9006 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9007 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9008 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9009 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
 9010 FORMAT(1X,35H                                   ,
     1             34H                                  ,
     1             I4,I5,I1)
      GO TO 20
C
C
C     ****************************************************************
C
C     LOAD OF BASIC DATA...NOT TIED TO THE START OF THE PROGRAM
C     ENDER FOR ALL LOAD SECTIONS IS A BLANK CARD
C
C     DEBUG LIMIT LOAD
C
 7700 DO 7704 JJ = 1,70
      XLOW(JJ) = 0.0001
      X(JJ) = 0.0
```

```
 7704 XHIGH(JJ) = 99999.0
      DO 7706 JJ = 1,9
      KLOW(JJ) = 1
 7706 KHIGH(JJ) = 9
      KHIGH(6)  = 99
      PAUSE 7708
C
C     LOAD LIST OF CAR NAMES
C
 7800 DO 7801 JJ = 1,10
      READ 9800,I,CMAKE(I)
 9800 FORMAT(I10,5X,A5)
      IF(I) 7802,7802,7801
 7801 CONTINUE
 7802 PAUSE 7802
C
C     LOAD LIST OF CITY NAMES
C
 7804 DO 7805 JJ=1,10
      READ 9800,I,CITY(I)
      IF(I) 7806,7806,7805
 7805 CONTINUE
 7806 PAUSE 7806
C
C     LOAD LAMINAR ELEMENT CALIBRATION FACTORS
C       FLOW, CFM, AT 0.4 IN. WATER DELTA P
C
 7900 DO 7901 JJ = 1,9
      READ 902,I,CAL(I)
      IF(I) 7902,7902,7901
 7901 CONTINUE
 7902 PAUSE 7902
C
C
C     LOAD LIMIT VECTORS FOR EACH X( ) INPUT VARIABLE
C
 8002 DO 8003 JJ=1,70
      READ 902,I,XLOW(I),XHIGH(I)
  902 FORMAT(I10,2F20.3)
      IF(I) 8004,8004,8003
 8003 CONTINUE
 8004 PAUSE 8004
C
C     LOAD LIMIT VECTORS FOR EACH K( ) INPUT VARIABLE
C
 8005 DO 8006 JJ=1,20
      READ 905,I,KLOW(I),KHIGH(I)
  905 FORMAT(3I10)
      IF(I) 8007,8007,8006
 8006 CONTINUE
 8007 PAUSE 8007
      GO TO 8007
C
C     ********************************************************************
C
C
```

```
C      READ FIRST DATA CARD OF SET OF FOUR
C        WITH TEST IF RUN NO. IS IN COL. 1-5 OR 2-6
C
   20 READ 915,J
  915 FORMAT(A1,79X)
      IF(J - 1H ) 520,516,520
  516 REREAD 916,KRUN,(X(I),I=2,12),(K(I),I=1,9)
  916 FORMAT(1X,A5,F1.0,F7.3,F6.0,F7.3,F7.2,2(F6.2,F6.3),2F6.1,
     1          5I1,I2,3I1)
      GO TO 522
  520 REREAD 920,KRUN,(X(I),I=2,12),(K(I),I=1,9)
  920 FORMAT  (A5,F2.0,F7.3,F6.0,F7.3,F7.2,F6.2,F6.3,F6.2,F6.3,2F6.1,
     1          5I1,I2,3I1)
  522 KODEA = 1000*K(1)+100*K(2)+10*K(3)+K(4)
      KODEB = 10000*K(5)+100*K(6)+10*K(7)+K(8)
      KODEC = K(9)
C
      TYPE 928,KRUN
  928 FORMAT(3HRUN,2X,A5)
C
      IF(10*K(8) + KODEC - 1) 22,28,22
C
   22 TYPE 922,KODEA, KODEB,KODEC
  922 FORMAT( 4HCARD,I6,I5,I1,13H OUT OF ORDER)
C
C     ABORT RUN
C
   24 IF(SENSE SWITCH 2) 1125,27
C
C     SW. 2 ON...NO OUTPUT FOR THIS RUN...GO TO NEXT RUN
C
 1125 IF(KODEC - 9) 25,26,25
   25 READ 925,KODEC
  925 FORMAT(79X,I1)
      IF(KODEC - 9) 25,26,25
   26 TYPE 926
  926 FORMAT(7HSKIPPED)
      GO TO 20
C
C     SW. 2 OFF...PAUSE TO PERMIT RELOAD
C
   27 PAUSE 27
      GO TO 20
C
   28 KA = KODEA
      KB = KODEB
C                  FOR CHECK OF THE RUN CODES ON SUCCEEDING CARDS
C
C     READ SECOND CARD OF SET OF FOUR
C
   30 READ 930,(X(I),I=13,23),KODEA,KODEB,KODEC
  930 FORMAT(F3.1,F4.0,F6.0,6X,F6.1,F6.3,2F6.0,2F7.2,F7.0,F6.2,
     1          I4,I5,I1)
      IF(KODEC - 2) 22,34,22
   34 IF(KODEA - KA) 22,36,22
   36 IF(KODEB - KB) 22,40,22
```

```
C
C     READ THIRD CARD OF SET OF FOUR
C
   40 READ 930,(X(I),I=24,34),KODEA,KODEB,KODEC
      IF(KODEC - 3)  22,44,22
   44 IF(KODEA - KA) 22,46,22
   46 IF(KODEB - KB) 22,50,22
C
C     READ FOURTH CARD OF SET OF FOUR
C
   50 READ 950,(X(I),I=35,45),KODEA,KODEB,KODEC
  950 FORMAT(F3.1,F4.0,F6.0,6X,F6.1,F6.3,2F6.4,F7.4,F7.3,F7.4,F6.3,
     1            I4,I5,I1)
   54 IF(KODEA - KA) 22,56,22
   56 IF(KODEB - KB) 22,57,22
   57 IF(KODEC - 4)  22,59,22
   59 NCOMM = 2
C
C
C     READ COMMENT CARDS WITH RUN DATA
C
   11 READ 9001,KODEA,KODEB,KODEC
      IF(KODEA - KA) 22,12,22
   12 IF(KODEB - KB) 22,13,22
   13 IF(KODEC - 5)  22,14,22
C
   14 READ 9002,KODEA,KODEB,KODEC
      IF(KODEA - KA) 22,15,22
   15 IF(KODEB - KB) 22,101,22
C
  101 REREAD 8101,TAMB,PAMB,HUMID
 8101 FORMAT(22X,F3.0,1X,F5.2,1X,F3.0)
C
   16 IF(KODEC - 9)  17,60,22
   17 IF(KODEC - 6)  22,18,22
C
C     READ UP TO 8 MORE COMMENT CARDS
C            LAST CARD CODED 9 IN COL. 80
C
   18 DO 122 I=3,10
      READ ICOMM(I),KODEA,KODEB,KODEC
      IF(KODEA - KA) 22,120,22
  120 IF(KODEB - KB) 22,121,22
  121 IF(KODEC - 9)  122,123,22
  122 CONTINUE
      I = 10
  123 NCOMM = I
C
C
C
C     THE FOUR CARDS ARE IN ORDER AND HAVE SAME RUN CODE
C       THERE ARE NCOMM COMMENTS CARDS AFTER THE FOUR
C       CARD SIX INCLUDES AMBIENT CONDITIONS DATA
C
C
C     ***************************************************************
```

```
C
C
C     NOW TEST THAT DATA LIE IN A REASONABLE RANGE
C     XLOW  OR KLOW  MEANS SMALLEST VALUE CONSIDERED TO BE A VALID INPUT
C     XHIGH OR KHIGH  MEANS LARGEST VALUE CONSIDERED TO BE A VALID INPUT
C     THESE WERE PRELOADED
C
C     TEST CODES
C
   60 DO 66 I=1,7
      IF (K(I)-KLOW(I))  64,62,62
   62 IF (K(I)-KHIGH(I)) 66,66,64
C
   64 TYPE 964,I,K(I),KLOW(I),KHIGH(I),KA,KB
  964 FORMAT( 2HK(,I1, 3H) =,I3,12H NOT BETWEEN,I3,4H AND,I3,
     1         7H ON SET, I6,I5,1H0)
      GO TO 24
C
   66 CONTINUE
C
C     CODES OK..TEST ALL DATA FOR MAGNITUDE
C
C     THE FOLLOWING ARE CONSIDERED ESSENTIAL VALUES AND MUST BE IN RANGE
C
C         KRUN        SERIAL RUN NUMBER
C         KLNO        SAMPLER NUMBER
C         ELMILE      MEASURED ELAPSED MILES
C         ODOM        ODOMETER READING... MILES
C         ELMIN       ELAPSED TIME IN MINUTES
C         DELP1       DELTA P...INCHES WATER...1
C         DELP2       DELTA P...INCHES WATER...2
C         DELP3       DELTA P...INCHES WATER...3
C         CPM1        INTEGRATOR CALIBRATIONS
C         CPM2          COUNTS
C         CPM3            PER MINUTE
C         CTN         COUNTS      NITROGEN
C         CTS         COUNTS      SAMPLER
C         CTC         COUNTS      CARBURETOR
C         GTDFN       GAS TEMP.   NITROGEN
C         GTDFS       GAS TEMP.   SAMPLER
C         GTDFC       GAS TEMP.   CARBURETOR
C         DEHCIR      DILUTE EXHAUST BAG DATA...HC-IR
C         DEHCFI      DILUTE EXHAUST BAG DATA...HC-FID
C         DECO        DILUTE EXHAUST BAG DATA...CO
C         DECO2       DILUTE EXHAUST BAG DATA...CO2
C         PAMB        AMBIENT AIR PRESSURE
C
  700 KNG = 0
      DO 704 I=1,34,11
      DO 704 J=1,4
      IF(I+J-3) 701,704,701
  701 IF(X(I+J)-XLOW(I+J)) 703,702,702
  702 IF(X(I+J)-XHIGH(I+J)) 704,704,703
  703 TYPE 9703, KRUN,I+J,X(I+J)
 9703 FORMAT(3HRUN,2X,A5,2X,2HX(,I2,3H) =,F11.4)
      KNG = 1
```

```
  704 CONTINUE
C
      DO 709 I=18,21
      IF(X(I) - XLOW(I)) 708,707,707
  707 IF(X(I) - XHIGH(I)) 709,709,708
  708 TYPE 9703,KRUN,I,X(I)
      KNG = 1
  709 CONTINUE
C
      IF(X(6) - XLOW(6)) 706,705,705
  705 IF(X(6)-XHIGH(6)) 710,710,706
  706 KNG = 1
      I = 6
      TYPE 9703, KRUN,I,X(6)
C
C     CHECK SAMPLER NUMBER
C
  710 JJ = X(2)
      IF(JJ - K(5)) 712,714,712
  712 TYPE 9712, KRUN,JJ,K(5)
 9712 FORMAT(3HRUN,2X,A5,2X,
     1        22HBAD SAMPLER NO. X(2) =,I3,7H K(5) =,I3)
      KNG = 1
C
C     CHECK RUN NUMBER
C
  714 IF(KRUN - 5H     )68,716,68
  716 TYPE 9716
 9716 FORMAT(10HNO RUN NO.)
      KNG = 1
C
C     CHECK AMBIENT BAROMETRIC PRESSURE
C
  810 IF(PAMB - 21.0)  814,814,812
  812 IF(PAMB - 32.0)  68,814,814
  814 TYPE 9814, KRUN,PAMB
 9814 FORMAT(3HRUN,2X,A5,
     1        24H WEATHER BUR. BAR. PR. =,F6.2,13H OUT OF RANGE)
      KNG = 1
C
   68 IF(KNG) 24,70,24
C
   70 KBAD = 0
      DO 82 I=2,48
C
C     TEST FOR MAGNITUDE..MAKE KBAD=1 IF ANY VALUE IS NG
C
   76 IF(X(I)-XLOW(I)) 80,78,78
   78 IF(X(I)-XHIGH(I)) 82,82,80
C
   80 TYPE 980, KRUN,I,X(I),XLOW(I),XHIGH(I)
  980 FORMAT(3HRUN,2X,A5,3H X(,I2,3H) =,
     1                       F11.4,4H NOT,F11.4,3H TO,F11.4)
      KBAD = 1
C
   82 CONTINUE
```

```
   85 IF(KBAD) 86,89,86
C
C     SW. 2 ON...GO AHEAD EVEN IF A MAGNITUDE IS BAD
C     SW. 2 OFF..TO THE RELOAD
C
   86 IF(SENSE SWITCH 2) 88,27
   88 TYPE 988
  988 FORMAT(13HMAGNITUDE BAD)
C
C     SW. 1 ON FOR EDIT MODE..NO CALC. OR OUTPUT
C
   89 IF(SENSE SWITCH 1) 20,90
C
C
C     ******************************************************************
C
C
C     NO VALUES BAD OR SW. 2 IS ON
C      ALL CALCULATED VALUES ARE REPLACED BY RECALCULATIONS.
C
C
C     DEVICE CODES...MX
C     MX = 1      NO DEVICE
C     MX = 2      C.A.P.
C     MX = 3      A.I.R.
C
   90 IF(K(3) - 1) 91,91,92
   91 MX = 1
      GO TO 95
   92 IF(K(4) - 2) 94,94,93
   93 MX = 2
      GO TO 95
   94 MX = 3
   95 FFDIL = 0.0
      KLNO = X(2)
C
C     LEAST-SQUARES AVERAGING OF INTEGRATOR CALIBRATION
C     DOES NOT REQUIRE THAT DELP1,DELP2,DELP3 BE IN 1/2/4 RATIO
C
  100 CPM =    0.4*(DELP1*CPM1+DELP2*CPM2+DELP3*CPM3)
     1             /(DELP1**2+DELP2**2+DELP3**2)
C
C     CAL(I) IS FLOW,CFM, OF LAMINAR ELEMENT(I) AT 0.4 IN. DELTA P
C     SAMPLER MUST HAVE SAME I AS ELEMENT
C     CAL(I) PRELOADED
C
  102 CFPCT = CAL(K(5))/CPM
C
C     AVERAGE MILES PER HOUR
C
  110 CMPH = 60.0*ELMILE/ELMIN
C
C     CORRECTION TERM = (528/(TEMP+460))**1.8
C
  140 DO 144 I=16,38,11
  144 X(I+1) = (528.0/(X(I)+460.0))**1.80
```

```
387 W = 0.20591289 + 6.7967068*R
    CECO2  = (W + SQRT (W*W - 5.6898101*R))/R
    GO TO 392
388 IF(R) 389,389,390
389 CECO2  = 11.700
    GO TO 392
390 W = -0.26875 + 7.243635*R
    CECO2  = (W + SQRT (W*W + 6.2887576*R))/R
C
C
C    CAF = A/F RATIO FROM CECO
C
392 CECO = R*CECO2
    IF(CECO - 2.2) 393,394,394
393 CAF = 12.42546 + 2.9963/(CECO + 0.5375)
    GO TO 281
394 CAF = 14.4 - 0.4*CECO
C
C    CALCULATE EXHAUST/AIR MOLE RATIO
C     GWT EQUATIONS FROM PHS MANUSCRIPT CURVE
C            SIMILAR TO FIG. 6 OF SMITH, ROSE, AND KRUSE PAPER
C
281 IF(CAF - 14.6) 282,282,284
282 CEARAT = 2.51068 - CAF*(0.28372 - CAF*(0.01781 - 0.000396*CAF))
    GO TO 286
284 CEARAT = 1.02010 - CAF*(0.013311 - 0.000500*CAF)
C
C    CALCULATE EXHAUST VOLUME   SCF PER MILE
C
286 CSCFEX = SCFAIR*CEARAT
C
C    EFFDIL...DILUTION RATIO FROM CO/CO2 CALCN.
C       USED AS SCALING-FACTOR TO GET ..CO/CO2 SCALED.. DATA
C       PROVIDED THAT IT IS NOT SMALLER THAN DILRAT
C
    EFFDIL = CECO2/DECO2
    FFDIL = EFFDIL
C
C    IF EFFDIL IS LESS THAN DILRAT, MAKE EFFDIL = DILRAT
C
    IF(EFFDIL - DILRAT) 287,395,395
287 EFFDIL = DILRAT
C
C    ..CO/CO2 SCALED.. UNDILUTED-EXHAUST-CONCENTRATIONS
C       FROM A SCALE-UP OF DILUTE-EXHAUST DATA BY EFFDIL
C
395 PCTAIR = 100.0*(EFFDIL - DILRAT)/(EFFDIL - DILRAT + 1.0)
    DO 396 I = 18,22
396 X(I+33) = EFFDIL*X(I)
C
C    UNDILUTED EXHAUST...LB/MILE
C
400 DO 402 I=1,5
    X(I+39) = C(I)*CSCFEX*X(I+28)
402 X(I+56) = C(I)*CSCFEX*X(I+50)
C
```

```
C
C     PRESSURE CORRECTION TO DRY GAS AT 1 ATM
C
      PWAT = 10.0**(6.767183 - 3213.24552/(TAMB + 395.8))
      PCORR = (PAMB - 0.01*HUMID*PWAT)/29.92126
C
C     COUNTS CORRECTED FOR TEMPERATURE AND PRESSURE
C
      CCTN = CTN*GTCFN*PCORR
      CCTS = CTS*GTCFS*PCORR
      CCTC = CTC*GTCFC*PCORR
C
C     CHECK ON SAMPLER TO CARBURETOR COUNT RATIO
C
  150 RATIO = CTS/CTC
C
C     CALCULATE AIR VOLUME     SCF PER MILE
C
  160 SCFAIR = CCTC*CFPCT/ELMILE
C
C     CALCULATE DILUTION RATIO FROM NITROGEN AND SAMPLER COUNTS
C
  200 DILRAT = 1.0 + CCTN/CCTS
C
C     SCALE UP DILUTE-EXHAUST DATA BY DILUTION RATIO TO GET
C        ...N2 SCALED... UNDILUTED-EXHAUST VALUES
C
  220 DO 226 I=18,23
  226 X(I+11)= DILRAT*X(I)
C
C     CALCULATE A/F RATIO FROM CO/CO2 RATIO
C      USING D ALLEVA AND LOVELL AND RECENT PHS EXPTL. DATA
C     NEW GWT EQUATIONS...MARCH 1, 1966
C
C     CO DECREASES TO ZERO AT A/F = 18.0
C     CO2 CURVES ROUNDED WITH MAX. AT 13.48 PER CENT CO2, A/F ± 14.13
C
C     RICH MEANS CO ABOVE 1.22 PER CENT..A/F = 14.13
C        CO/CO2 RATIO ABOVE 0.09053
C
C     STEADY-STATE-EQUILIBRIUM CO AND CO2 FROM BAG CO/BAG CO2
C     THAT IS...CECO AND CECO2 FROM R = DECO/DECO2
C
  340 R = DECO/DECO2
  380 IF(R - 0.1971) 382,381,381
  381 CECO2  = 22.875/(1.5625 + R)
      GO TO 392
  382 IF(R - 0.1669) 384,383,383
  383 W = 1.9105 + 6.9*R
      CECO2  = (W - SQRT (W*W - 51.72305*R))/R
      GO TO 392
  384 IF(R - 0.09053) 386,385,385
  385 W = 3.0892766 + 7.3513157*R
      CECO2  = (W - SQRT (W*W - 84.776705*R))/R
      GO TO 392
  386 IF(R - 0.05446) 388,387,387
```

```
C     CALCULATE MILES PER GAL.  61.0 API GRAVITY
C     FUEL TAKEN HERE TO BE CH2      MW = 14.027 PER ATOM C
C     HYDROCARBON EFFLUENT           MW = 13.857 PER ATOM C
C
  332 UMPGAL = 6.119/(1.01227*EWHCFI + 0.31872*EWCO2 + 0.50077*EWCO)
      CMPGAL = 6.119/(1.01227*CWHCFI + 0.31872*CWCO2 + 0.50077*CWCO)
C
C
C     SCALE RESULTS FOR OUTPUT CARDS
C
  420 Z = 10000.0
      R = 0.5
      AF = CAF
      EARAT = CEARAT
      SCFEXH = CSCFEX
C
      V(1) = Z*X(7) + R
      V(2) = Z*X(11) + R
      V(3) = Z*X(12) + R
C
      DO 430 I=6,36
  430 V(I) = Z*X(I+25) + R
C
      DO 435 I=4,26,22
      V(I)   = X(I+25) + R
      V(I+1) = X(I+26) + R
  435 V(I+4) = X(I+29) + R
C
      IF(X(46)) 436,440,440
  436 V(21) = Z*X(46) - R
C
C     FORMAL EQUALITY OF EMISSION WEIGHTS AND MILES PER GAL.
C        FOR THE A.I.R. SYSTEM EQUIPPED CARS
C
  440 IF(MX - 2) 1092,1092,442
  442 DO 444 I=15,19
      V(I+17) = V(I)
  444 X(I+42) = X(I+25)
      CMPGAL = UMPGAL
C
C
C     ***********************************************************************
C
C     SKIP PUNCH OF SUMMARY IF SW. 3 IS ON
C
 1092 IF(SENSE SWITCH 3)  1115,6000
C
C
C     RUN SUMMARY OUTPUT
C
C
 9991 FORMAT(1H1)
 6000 PUNCH 9600
 9600 FORMAT(1H1,13X,41HETHYL CORPORATION - PUBLIC HEALTH SERVICE)
      PUNCH 9601
 9601 FORMAT(16X,38HEXHAUST EMISSION SURVEILLANCE CONTRACT/)
```

```
      PUNCH 9602,KRUN,ODOM
 9602 FORMAT(16H SUMMARY FOR RUN, 2X,A5,25X,8HODOMETER,I14)
      PUNCH 9603,ELMILE
 9603 FORMAT (35X,9HGAS TEMP.,4X,11HOBS.  MILES,F11.3)
      PUNCH 9604,CITY(K(1)),ELMIN
 9604 FORMAT(5H CITY,8X,A5,17X,10(1H.),16H   OBS.  MINUTES,F9.2)
      PUNCH 9605,K(2),CMPH
 9605 FORMAT(6H VISIT,I9,13X,34HCOUNT  DEG. CORR.   CALC. MILES/HR,
     1        F8.2)
      PUNCH 9606,N3(MX),N4(MX),RATIO
 9606 FORMAT(7H DEVICE,7X,2A3,28X,11HCOUNT RATIO,F11.3)
      PUNCH 9607,CMAKE(K(4)), CTN,GTDFN,GTCFN,CPM
 9607 FORMAT(9H CAR MAKE,4X,A5,5X,4HNITR,I6,F5.0,F6.3,4X,
     1        15HAVE. COUNTS/MIN,F7.1)
      PUNCH 9608,K(5),CTS,GTDFS,GTCFS,CFPCT
 9608 FORMAT(8H SAMPLER,I7,8X,4HSAMP,I6,F5.0,F6.3,4X,
     1        14HCUB. FT./COUNT,F8.3)
      PUNCH 9610,K(6),CTC,GTDFC,GTCFC,SCFAIR
 9610 FORMAT(11H CAR NUMBER,I4,8X,4HCARB,I6,F5.0,F6.3,4X,
     1        12HSCF AIR/MILE,F10.1/)
      PUNCH 9612,N1(K(7)),N2(K(7))
 9612 FORMAT(1X,2A3,16H RUN ON THIS CAR/)
      IF(K(7) - 2) 613,613,612
  612 K(7) = 2
  613 PUNCH 9613
 9613 FORMAT(22X,20HFROM NITROGEN COUNTS,6X,
     1        18HFROM CO/CO2 CALCN./)
 1614 PUNCH 8617,CAF
 8617 FORMAT(19H AMBIENT CONDITIONS,30X,
     1             14HAIR/FUEL RATIO,F7.2)
  618 PUNCH 9618,DILRAT,EFFDIL
 9618 FORMAT(18X,2(5X,14HDILUTION RATIO,F7.3))
 1619 PUNCH 8619,TAMB,CEARAT
 8619 FORMAT(6H TEMP.,4X,  I5,2H F,32X,
     1             14HEXH/AIR  RATIO,F7.3)
      PUNCH 8620,PAMB,CSCFEX
 8620 FORMAT(9H PRESSURE,F6.2,4H IN.,30X,
     1             12HSCF EXH/MILE,F9.1)
      IF (MX - 2) 621,621,1621
 1621 PUNCH 8621,HUMID,UMPGAL
 8621 FORMAT(9H HUMIDITY,I6,4H PCT,30X,
     1             12HMILES/GALLON,F9.1//)
      GO TO 1622
  621 PUNCH 9621,HUMID,UMPGAL,CMPGAL
 9621 FORMAT(9H HUMIDITY,I6,4H PCT,
     1             2(4X,12HMILES/GALLON,F9.1,1X)//)
 1622 PUNCH 8622
      PUNCH 9622
      PUNCH 9623
 8622 FORMAT(22X,23H....NITROGEN SCALED....,
     1         3X,23H....CO/CO2 SCALED.....)
 9622 FORMAT(19H EFFLUENT  DILUTE  ,2(26H   UNDILUTED  EMISSION WT.))
 9623 FORMAT(11X,7HEXHAUST,2(26H      EXHAUST     LB/MILE  )/)
      IF(MX - 2) 624,624,1624
 1624 PUNCH 9624,DEHCIR,V(4),EWHCIR,V(26)
      PUNCH 9625,DEHCFI,V(5),EWHCFI,V(27)
```

```
      PUNCH 9626,DENOX,V(8),EWNOX,V(30)
      PUNCH 9112
      PUNCH 9627,DECO,UECO,EWCO,CECO
      PUNCH 9628,DECO2,UECO2,EWCO2,CECO2
      GO TO 629
  624 PUNCH 9624,DEHCIR,V(4),EWHCIR,V(26),CWHCIR
 9624 FORMAT(8H HC NDIR,I6,5H PPMC,2(I8,5H PPMC,F10.4,3X))
      PUNCH 9625,DEHCFI,V(5),EWHCFI,V(27),CWHCFI
 9625 FORMAT(7H HC FID,I7,5H PPMC,2(I8,5H PPMC,F10.4,3X))
      PUNCH 9626,DENOX,V(8),EWNOX,V(30),CWNOX
 9626 FORMAT(4H NOX,I10,4H PPM,2(I9,4H PPM,F11.4,2X)/)
      PUNCH 9627,DECO,UECO,EWCO,CECO,CWCO
 9627 FORMAT(3H CO,F11.2,4H PCT,2(F9.2,4H PCT,F11.4,2X))
      PUNCH 9628,DECO2,UECO2,EWCO2,CECO2,CWCO2
 9628 FORMAT(4H CO2,F10.2,4H PCT,2(F9.2,4H PCT,F11.4,2X))
C
  629 PUNCH 9629,DEO2,UEO2
 9629 FORMAT(3H O2,F11.2,4H PCT,F9.2,4H PCT//)
      IF(FFDIL - DILRAT) 630,1108,1108
  630 PUNCH 9630,FFDIL,DILRAT
 9630 FORMAT(32H DIL. RATIO FROM CO/CO2 CALCN. =,F6.3,
     1        14H IS LOWER THAN,F6.3,21H FROM NITROGEN COUNTS//)
C
C     PUNCH COMMENT CARDS IF ANY.....DELETING THE CODES
C
 9112 FORMAT(1H )
 1108 IF(NCOMM) 1115,1115,1109
 1109 DO 1110 I=1,NCOMM
 1110 PUNCH ICOMM(I)
C
C
C     *********************************************************************
C
C     PUNCH OUTPUT USED AS INPUT FOR DELS PROGRAM
C           AND AS INPUT FOR ANOVA
C
 1115 PUNCH 9115,KRUN
 9115 FORMAT(/41H1OUTPUT CARDS FOR FUTURE ANALYSIS OF DATA,
     1         23H ARE LISTED BELOW...RUN,2X,A5/)
C
C     CITY,VISIT,DEVICE,CAR MAKE,REPEAT RUN,CAR NO.,MPH,ODOMETER
C
 8120 PUNCH 9120,(K(I),I=1,4),K(7),K(6),V(1),X(4),KA,KB/10
 9120 FORMAT(I3,5I7,4X,2I7,14X,2I4,2H31)
C
C     PER CENT UNDILUTED EXHAUST..HCIR,HCFID,CO,CO2,NOX,O2
C           SCALED SO THAT OUTPUT IS IN PPM
C              ..CO/CO2 SCALED..  DATA
C           THEN AMBIENT CONDITIONS
C
      PUNCH 8121,(V(I),I=26,30),V(9),(V(I),I=21,23),KA,KB/10
 8121 FORMAT(9I7,7X,2I4,2H32)
C
C     EMISSION WEIGHT, LB/MILE....HCIR,HCFID,CO,CO2,NOX
C           SCALED TIMES 10000
C              ..N2 SCALED..  DATA
```

```
C           CARBURETOR TEMPERATURE,SCFAIR,CSCFEX
C
      PUNCH 9122,(V(I),I=15,19),V(13),V(2),V(25),KA,KB/10
 9122 FORMAT(8I7,14X,2I4,2H33)
C
C     PER CENT UNDILUTED EXHAUST..HCIR,HCFID,CO,CO2,NOX,O2
C          SCALED SO THAT OUTPUT IS IN PPM
C             ..N2 SCALED..  DATA
C          THEN AMBIENT CONDITIONS
C
      PUNCH 9121,(V(I),I=4,9),(V(I),I=21,23),KA,KB/10
 9121 FORMAT(9I7,7X,2I4,2H34)
C
C
C     EMISSION WEIGHT, LB/MILE....HCIR,HCFID,CO,CO2,NOX
C          SCALED TIMES 10000
C             ..CO/CO2 SCALED..  DATA
C             SAME AS ..N2 SCALED.. FOR A.I.R. CARS
C          CARBURETOR TEMPERATURE,SCFAIR,CSCFEX
C
      PUNCH 9125,(V(I),I=32,36),V(13),V(2),V(25),KA,KB/10
 9125 FORMAT(8I7,14X,2I4,2H35//)
C
C
C     MAKE THE REFURBISHED DATA DECK
C     USUAL   CARD 03 HAS ..CO/CO2 SCALED.. UNDILUTED-EXHAUST-CONCN.
C     SPECIAL CARD 07 HAS ..N2 SCALED..     UNDILUTED-EXHAUST-CONCN.
C        THAT IS,  TAILPIPE-EXHAUST-CONCN.
C     USUAL   CARD 04 HAS ..N2 SCALED..     EMISSION WT.:LB/MILE
C
  740 PUNCH 9721,KRUN,(X(I),I=2,7),DILRAT,CAF,CEARAT,X(11),X(50),KA,KB
      PUNCH 9722,(X(I),I=13,23),KA,KB
      PUNCH 9723,(X(I),I=24,26),CMPGAL,X(27),X(28),V(26),V(27),
     1           X(53),X(54),V(30),X(34),KA,KB
      PUNCH 9724,(X(I),I=35,45),KA,KB
 9721 FORMAT(1X,A5,I1,F7.3,I6,F7.3,F7.2,2(F6.2,F6.3),
     1       2F6.1,I4,I5,1H1)
 9722 FORMAT(F3.1,I4,I6,F12.1,F6.3,2I6,2F7.2,I7,F6.2,I4,I5,1H2)
 9723 FORMAT(F3.1,I4,I6,F6.1,F6.1,F6.3,2I6,2F7.2,I7,F6.2,I4,I5,1H3)
 9727 FORMAT(7X,F6.1,F6.1,12X,2I6,2F7.2,I7,F6.2,I4,I5,1H7)
 9724 FORMAT(F3.1,I4,I6,F12.1,F6.3,2F6.4,F7.4,F7.3,F7.4,F6.3,I4,I5,1H4)
  725 I = 5
      PUNCH 9001,KA,KB,I
      I = 6
      PUNCH 9002,KA,KB,I
      PUNCH 9727,PCTAIR,UMPGAL,V(4),V(5),X(31),X(32),V(8),X(34),KA,KB
      IF(NCOMM - 3) 730,730,726
  726 J = 8
      DO 728 I=3,NCOMM - 1
  728 PUNCH ICOMM(I),KA,KB,J
  730 J = 9
      PUNCH ICOMM(NCOMM),KA,KB,J
      GO TO 20
      END
*     ECJ      TRAILER  VERSIONS...GWT
```

Preload for Computer Program TRAILR

1	CHEV
2	FORD
3	PLYM

1	DENV
2	HOUS
3	MINN
4	PHNX
5	CINC

1	66.0
2	63.0
3	66.0
4	63.0

1	0.0001	99999.0
2	1.0	9.0
3	0.0	1.0
4	50.00	30000.0
5	7.0	9.0
6	10.0	30.0
7	0.0	50.0
8	0.0	6.0
9	0.0	20.0
10	0.0	1.4
11	0.0	200.0
12	0.0	200.0
13	0.1	0.3
14	70.0	110.0
15	1000.0	8000.0
16	-20.0	120.0
17	0.0	2.0
18	150.0	2000.0
19	200.0	3000.0
20	0.0	5.0
21	1.5	10.0
22	30.0	2000.0
23	0.1	5.0
24	0.3	0.5
25	170.0	200.0
26	100.0	4000.0
27	-20.0	120.0
28	0.0	2.0
29	0.0	5000.0
30	0.0	9999.9
31	0.0	10.0
32	0.0	20.0
33	0.0	5000.0
34	0.0	20.0
35	0.6	0.9
36	300.0	400.0
37	100.0	4000.0
38	-20.0	120.0

39	0.0	2.0
40	0.0	0.1
41	0.0	0.1
42	0.0	0.6
43	0.0	2.0
44	0.0	0.1
45	0.0	1.2
46	-30.0	120.0
47	21.0	32.0
48	0.0	100.0

1	1	6
2	1	9
3	1	2
4	1	3
5	1	9
6	1	99
7	1	2
8	0	1
9	1	9

APPENDIX II. STEADY-STATE CO, CO_2, A/F RELATIONS

The usual method of relating the exhaust gas composition to the air-fuel ratio (A/F) in an internal combustion engine is by means of a theoretical relationship similar to the calculations of B. A. D'Alleva and W. G. Lovell, S.A.E. Journal, 38, No. 3, 90-98, 116 (1936). The C/H ratio of the fuel must be known as well as the amount and C/H ratio of hydrocarbon effluents. A water-gas equilibrium constant must also be assumed at some equivalent temperature. Systematic deviations from these "theoretical" curves have been noted both for single-cylinder and multicylinder engines. In the D'Alleva-Lovell work (abbreviated D'A-L below) the rich-side CO_2 was too high by about 0.5 per cent, and the lean-side CO_2 was too low by as much as 1.0 per cent. The CO was too low by as much as 0.5 to 1.0 per cent and both oxygen and CO were observed on both sides of the "stoichiometric" limit.

A different approach has been taken in this investigation. Experimental CO and CO_2 data are correlated against experimental A/F for two sets of multicylinder engine data. These comprised 49 data points from D'A-L and 27 data points obtained with a 283 cu. in. Chevrolet engine using Indolene and also a "commercial regular" fuel (9 other data points using isooctane were not used). These were sent by L. C. Broering, Jr. to C. Walcutt on Feb. 21, 1966 and are said to be the best data obtained at the Public Health Service at Cincinnati. (These are designated LCB below.)

This collection of 73 data points is believed to be a good representative sample of multicylinder engine data as a whole. The newer data provide an excellent confirmation of the older work.

A plot of the CO data vs A/F showed that the D'A-L data had considerably less spread than LCB, that the two sets of data were in general agreement, and that both confirmed the presence of CO on the "lean" side. The CO decreased steadily and was still appreciable up to about A/F = 18.0. Two empirical equations gave an adequate representation. For A/F ratios up to about 13.52 a straight line was adequate

$$Y = 14.4 - 0.40 X \qquad (1A)$$

where X = 2.2 to 13.5% CO and Y is A/F for the range 9.00 to 13.52. After careful consideration of the plotted data for the higher A/F it was decided that a smooth curve could be drawn which would contact the line at 2.2% CO and become zero at A/F = 18.0. The curve is represented by the hyperbola

$$Y = 12.42546 + 2.9963/(X + 0.5375). \qquad (1B)$$

where X = 0.0 to 2.2% CO and Y is A/F for the range 13.52 to 18.0.

Examination of a plot of the CO_2 data showed that the CO_2 - A/F relationship was not well defined, especially above A/F = 13. Near the peak (between A/F - 14 and 15), the spread in the CO_2 content was $\pm$ 1.0%. The shape of the theoretical curves was kept in mind in choosing the following four-part representation for CO_2 which gives the greatest weight to D'A-L.

$$\underline{X = 6 \text{ to } 13\%\ CO_2;\ Y = A/F = 9 \text{ to } 13.375} \qquad (2A)$$

$$Y = 5.25 + 0.635X$$

$$\underline{X = 13.00 \text{ to } 13.48\%\ CO_2;\ Y = A/F = 13.375 \text{ to } 14.13} \qquad (2B)$$

$$Y = 12.8716 + 0.4027/(13.8 - X)$$

$$\underline{X = 13.48 \text{ to } 13.30\%\ CO_2;\ Y = A/F = 14.13 \text{ to } 14.80} \qquad (2C)$$

$$Y = 15.5817 - 0.30485/(13.69 - X)$$

$$\underline{X = 13.30 \text{ to } 11.7\%\ CO_2;\ Y = A/F = 14.80 \text{ to } 18.0} \qquad (2D)$$

$$Y = 41.4 - 2.0X$$

Equations 2A and 2D were fitted first and provide a reasonable representation except for the region near 14 to 15 A/F. These equations intersect at A/F = 13.86 and 13.77% CO_2. The sections near the top were approximately rounded off by eye. The curved section was fitted by two intersecting hyperbolas, equations 2B and 2C which contact the two lines reasonably. The match point of 2B and 2C is 13.48% CO_2 and A/F = 14.13; calculated CO = 1.2203%.

The equations above can also be expressed in terms of CO_2 from CO/CO_2 at the same A/F ratio. The five relationships are shown in the attached table. They correspond to the simultaneous solution of equations:

1A for CO and 2A for CO_2	Rich
1A for CO and 2B for CO_2	Rich
1B for CO and 2B for CO_2	Rich
1B for CO and 2C for CO_2	Lean
1B for CO and 2D for CO_2	Lean

In using these relations, the criterion of "Lean" given in Rule 1 is satisfactory. It is based on the match point of equations 2B and 2C.

Rule 1

When using the CO/CO_2 relations, the "Lean" criterion is CO/CO_2 less than 0.09052.

Air/Fuel ratio range	CO/CO_2 range	Equation for $Y = CO_2$ as function of $X = CO/CO_2$
9.000 to 13.375	2.25 to 0.197115	$Y = 22.875/(1.5625 + X)$
13.375 to 13.520	0.197115 to 0.166933	$W = 1.9105 + 6.9X$ $Y = [W - \sqrt{W^2 - 51.72305X}]/X$
13.520 to 14.130	0.166933 to 0.090526	$W = 3.0892766 + 7.3513157X$ $Y = [W - \sqrt{W^2 - 84.778705X}]/X$
14.130 to 14.800	0.090526 to 0.054462	$W = 0.20591289 + 6.7967068X$ $Y = [W + \sqrt{W^2 - 5.6898101X}]/X$
14.800 to 18.000	0.054462 to 0.000000	$W = -0.26875 + 7.243635X$ $Y = [W + \sqrt{W^2 + 6.2887576X}]/X$

Tables 3 and 4 show the experimental CO, CO_2 and A/F data and calculated values and deviations for A/F from CO, A/F from CO_2, A/F from CO/CO_2, and CO_2 from CO/CO_2. 86% of the differences between observed A/C and that calculated from CO/CO_2 lie within 0.7 units with 62% within 0.3 units. The poorest fit is on the lean side at high A/F, where the scatter of the data is wide. However, the effect on the exhaust/air (E/A) ratio is small. On the lean side E/A changes by less than 0.004 per A/F. On the rich side, E/A changes by about 0.03 per A/F. If the lean side error of fit is taken to be about 1.0 unit in A/F, this corresponds to 0.004 in E/A. On the rich side the value is 0.4 unit in A/F corresponding to about 0.012 in E/A. On the whole, the error in the lb/mile of effluents is thus less than one per cent because of the uncertainty in estimating the air-fuel ratio.

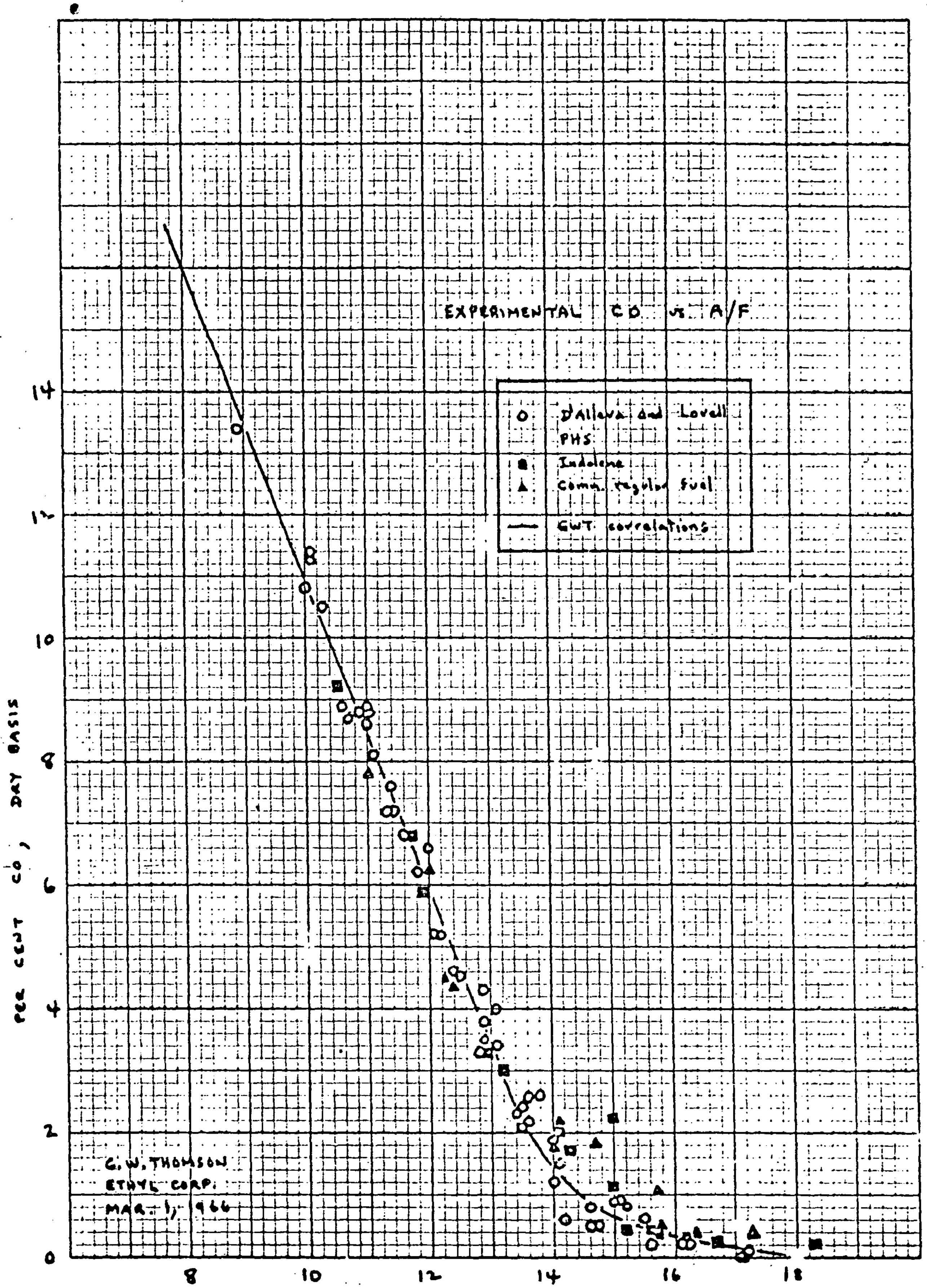

Fig. 5.' AIR/FUEL RATIO 36a

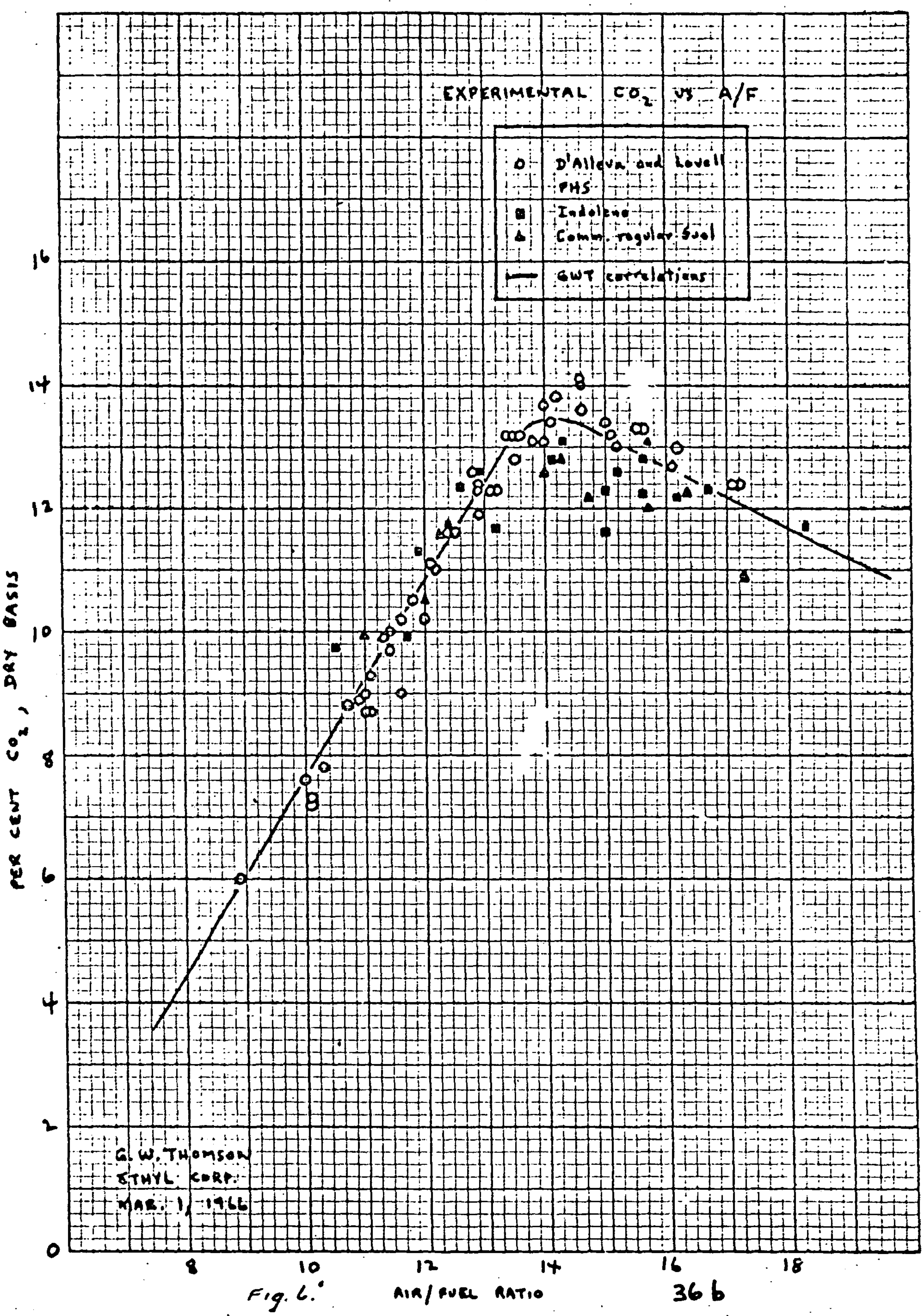
EXPERIMENTAL CO_2 VS A/F
D'Alleva and Lovell
FHS
Indolene
Comm. regular fuel
GWT correlations
PER CENT CO_2, DRY BASIS
0
2
4
6
8
10
12
14
16
8
10
12
14
16
18
AIR/FUEL RATIO
G. W. THOMSON
ETHYL CORP.
MAR. 1, 1966

Fig. 6.

Table 3. CO, CO_2, A/F Data. D'Alleva and Lovell measurements.

No.	CO	CO_2	CO/CO_2	obs. A/F	From CO A/F	From CO Diff.	From CO_2 A/F	From CO_2 Diff.	From CO/CO_2 A/F	From CO/CO_2 Diff.	From CO/CO_2 CO_2	From CO/CO_2 Ratio
1	7.2	9.9	0.727	11.3	11.52	+0.22	11.44	+0.14	11.49	+0.19	9.991	1.009
2	8.9	9.0	0.989	10.6	10.84	+0.24	10.88	+0.28	10.85	+0.25	8.965	0.995
3	2.2	13.2	0.167	13.6	13.52	-0.08	13.54	-0.06	13.52	-0.08	13.179	0.998
4	0.8	13.0	0.062	15.2	14.67	-0.53	15.40	+0.20	14.62	-0.58	13.374	1.029
5	4.0	12.3	0.325	13.1	12.80	-0.30	12.94	-0.16	12.83	-0.53	12.119	0.985
6	8.1	9.3	0.871	11.1	11.16	+0.06	11.06	-0.04	11.13	+0.03	9.400	1.011
7	5.2	11.0	0.464	12.2	12.32	+0.12	12.13	-0.07	12.31	+0.11	11.288	1.026
8	10.5	7.8	1.346	10.3	10.20	-0.10	10.13	-0.17	10.17	-0.13	7.865	1.008
9	2.6	13.1	0.198	13.8	13.36	-0.44	13.45	-0.35	13.37	-0.43	12.993	1.008
10	3.3	12.6	0.262	12.8	13.08	+0.28	13.13	+0.33	13.09	+0.29	12.538	0.995
1	4.3	11.9	0.361	12.9	12.68	-0.22	12.69	-0.21	12.68	-0.22	11.892	0.999
2	3.4	12.3	0.276	13.1	13.04	-0.06	12.94	-0.16	13.03	-0.07	12.442	1.012
3	6.6	10.2	0.647	12.0	11.76	-0.24	11.63	-0.37	11.72	-0.28	10.353	1.015
4	8.6	8.7	0.989	11.0	10.96	-0.04	10.69	-0.31	10.86	-0.14	8.965	1.030
5	8.9	8.7	1.023	11.0	10.84	-0.16	10.69	-0.31	10.78	-0.22	8.847	1.017
6	11.4	7.3	1.562	10.1	9.84	-0.26	9.81	-0.29	9.83	-0.27	7.321	1.003
7	11.3	7.2	1.569	10.1	9.88	-0.22	9.75	-0.35	9.82	-0.28	7.305	1.015
8	2.4	12.8	0.188	13.5	13.44	-0.06	13.25	-0.25	13.42	-0.08	13.063	1.020
9	1.5	13.4	0.112	14.1	13.90	-0.20	13.88	-0.22	13.89	-0.21	13.406	1.000
10	0.8	13.6	0.059	14.6	14.67	+0.07	14.13	-0.37	14.69	+0.09	13.349	0.982
11	0.9	13.4	0.067	15.0	14.51	-0.49	14.53	-0.47	14.51	-0.49	13.405	1.031
12	0.6	13.3	0.045	15.5	15.06	-0.44	14.80	-0.70	15.06	-0.42	13.161	0.990
13	0.2	12.7	0.016	16.1	16.49	+0.39	16.00	-0.10	16.49	+0.39	12.454	0.981
14	0.0	12.4	0.000	17.1	18.00	+0.90	16.60	-0.50	18.00	+0.90	11.700	0.944
1	0.2	13.0	0.015	16.2	16.49	+0.29	15.40	-0.80	16.56	+0.36	12.417	0.955
2	0.1	12.4	0.008	17.2	17.13	+0.07	16.60	-0.60	17.15	-0.05	12.126	0.978
3	1.9	13.1	0.145	14.0	13.65	-0.35	13.45	-0.55	13.65	-0.35	13.277	1.014
4	0.9	13.2	0.068	15.1	14.51	-0.59	15.00	-0.10	14.49	-0.61	13.410	1.016
5	4.5	11.6	0.388	12.5	12.60	+0.10	12.50	0.00	12.58	+0.08	11.728	1.011
6	7.2	10.0	0.720	11.4	11.52	+0.12	11.50	+0.10	11.51	+0.11	10.022	1.002
7	13.4	6.0	2.233	8.9	9.4	+0.14	9.00	+0.10	9.02	+0.12	6.027	1.005
8	8.8	8.9	0.989	10.9	10.88	-0.02	10.81	-0.09	10.85	-0.05	8.965	1.007
9	8.8	9.0	0.978	11.0	10.88	-0.12	10.88	-0.12	10.88	-0.12	9.004	1.000
10	6.8	10.2	0.667	11.6	11.68	+0.08	11.63	+0.03	11.66	+0.06	10.260	1.006
11	3.8	12.3	0.309	12.9	12.88	-0.02	12.94	+0.04	12.26	-0.64	12.223	0.994
12	2.5	13.1	0.193	13.6	13.36	-0.24	13.45	-0.15	13.37	-0.23	12.993	0.992
13	0.5	14.0	0.036	14.6	15.31	+0.71	14.13	-0.47	15.41	+0.81	12.997	0.928
14	0.2	13.3	0.015	15.6	16.49	+0.89	14.80	-0.80	16.57	+0.97	12.417	0.934
15	0.6	13.8	0.043	14.2	15.06	+0.86	14.13	-0.07	15.14	+0.94	13.128	0.951
16	2.3	13.2	0.174	13.4	13.48	+0.08	13.54	+0.14	13.48	+0.08	13.144	0.996
17	4.6	11.6	0.397	12.4	12.56	-0.16	12.50	+0.10	12.54	+0.14	11.674	1.006
18	6.2	10.5	0.590	11.8	11.92	+0.12	11.81	+0.01	11.69	+0.09	10.627	1.012
19	8.7	8.8	0.989	10.7	10.92	+0.22	10.75	+0.05	10.85	+0.15	8.965	1.019
20	10.8	7.6	1.421	10.0	10.08	+0.08	10.00	0.00	10.04	+0.04	7.667	1.009
21	7.6	9.7	0.784	11.4	11.36	-0.04	11.31	-0.09	11.34	-0.06	9.749	1.005
22	5.2	11.1	0.468	12.1	12.32	+0.12	12.19	+0.09	12.29	+0.19	11.266	1.015
23	3.5	12.4	0.282	12.9	13.00	+0.10	13.00	+0.10	13.00	+0.10	12.402	1.000
24	1.2	13.7	0.088	14.0	14.15	+0.15	14.13	+0.13	14.16	+0.16	13.475	0.984
25	0.5	14.1	0.035	14.6	15.31	+0.71	14.13	-0.47	15.41	+0.81	12.977	0.920

Table 4. CO, CO_2, A/F Data. PHS Data.

NO.	CO	CO_2	CO/CO_2	Obs A/F	From CO: A/F	From CO: Diff.	From CO_2: A/F	From CO_2: Diff.	From CO/CO_2: A/F	From CO/CO_2: Diff.	From CO/CO_2: CO_2	From CO/CO_2: Ratio
Indolene												
	2.05	12.35	0.164	13.6	13.59	-0.01	12.97	-0.63	13.53	-0.07	13.193	1.068
	1.13	12.3	0.092	15.0	14.22	-0.78	16.80	+1.80	14.11	-0.89	13.475	1.096
	9.25	9.75	0.949	10.5	10.70	+0.20	11.34	+0.84	10.94	+0.44	9.108	0.934
	5.9	11.3	0.522	11.9	12.04	+0.14	12.31	+0.41	12.11	+0.21	10.974	0.971
	3.3	12.6	0.262	12.9	13.08	+0.18	13.13	+0.23	13.09	+0.19	12.538	0.995
	2.0	12.8	0.156	14.1	13.61	-0.49	13.25	-0.85	13.58	-0.52	13.229	1.034
	0.23	12.3	0.019	16.7	16.33	-0.37	16.80	+0.10	16.28	-0.42	12.557	1.021
	3.0	11.7	0.256	13.2	13.20	0.00	12.56	-0.64	13.11	-0.09	12.579	1.075
	0.45	12.6	0.036	15.2	15.46	+0.26	16.20	+1.00	15.40	+0.20	12.997	1.032
	0.25	12.15	0.021	16.15	16.23	+0.08	17.10	+0.95	16.16	+0.01	12.620	1.039
	6.75	9.95	0.678	11.7	11.70	0.00	11.47	-0.23	11.63	-0.07	10.210	1.026
	0.45	12.25	0.037	15.6	15.46	-0.14	16.90	+1.30	15.37	-0.23	13.017	1.064
	0.20	11.7	0.017	18.3	16.49	-1.81	18.00	-0.30	16.42	-1.88	12.489	1.067
	1.73	13.1	0.132	14.3	13.75	-0.55	13.45	-0.85	13.74	-0.56	13.331	1.016
	0.45	12.8	0.035	15.6	15.46	-0.14	15.80	+0.20	15.45	-0.15	12.977	1.014
	2.25	11.6	0.194	15.0	13.50	-1.50	12.50	-2.50	13.39	-1.61	13.022	1.123
Commercial regular gasoline												
	1.05	12.0	0.088	15.7	14.31	-1.39	17.40	+1.70	14.16	-1.54	13.475	1.123
	1.85	12.15	0.152	14.7	13.68	-1.02	12.84	-1.86	13.60	-1.10	13.247	1.090
	6.15	10.5	0.586	12.0	11.94	-0.06	11.81	-0.19	11.91	-0.09	10.647	1.014
	[illegible].37	10.9	0.034	17.3	15.73	-1.57	19.42	+2.12	15.49	-1.81	12.955	1.189
	2.05	12.8	0.160	14.1	13.58	-0.52	13.25	-0.85	13.55	-0.55	13.211	1.032
	7.75	9.95	0.779	11.0	11.30	+0.30	11.47	+0.47	11.36	+0.36	9.769	0.982
	4.35	11.6	0.375	12.35	12.66	+0.31	12.50	+0.15	12.63	+0.28	11.806	1.018
	0.37	12.15	0.030	16.25	15.73	-0.52	17.10	+1.85	15.67	-0.58	12.865	1.059
	1.97	12.6	0.156	14.0	13.62	-0.38	13.13	-0.87	13.57	-0.43	13.229	1.050
	4.5	11.7	0.385	12.35	12.60	+0.25	12.56	+0.21	12.59	+0.14	11.746	1.004
	0.25	13.1	0.019	15.7	16.23	+0.53	15.20	-0.50	16.29	+0.59	12.557	0.959

APPENDIX III. TABLES

Individual calculations are most easily carried out using the set of tables included with this report. These tables are based on the identical equations and relations discussed in the text and used in the computer program. They include

A/F from CO

A/F from CO_2 (rich)

A/F from CO_2 (lean)

CO_2 from CO/CO_2

E/A from A/F

Temperature correction term for gas volumes to 68°F

Vapor pressure of water

AIR/FUEL RATIO FROM CARBON MONOXIDE

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	18.00	17.90	17.80	17.71	17.61	17.53	17.44	17.36	17.28	17.20
.1	17.13	17.05	16.98	16.91	16.85	16.78	16.72	16.66	16.60	16.54
.2	16.49	16.43	16.38	16.33	16.28	16.23	16.18	16.14	16.09	16.05
.3	16.00	15.96	15.92	15.88	15.84	15.80	15.76	15.73	15.69	15.66
.4	15.62	15.59	15.55	15.52	15.49	15.46	15.43	15.40	15.37	15.34
.5	15.31	15.29	15.26	15.23	15.21	15.18	15.16	15.13	15.11	15.08
.6	15.06	15.04	15.01	14.99	14.97	14.95	14.93	14.91	14.89	14.87
.7	14.85	14.83	14.81	14.79	14.77	14.75	14.73	14.72	14.70	14.68
.8	14.67	14.65	14.63	14.62	14.60	14.58	14.57	14.55	14.54	14.52
.9	14.51	14.50	14.48	14.47	14.45	14.44	14.43	14.41	14.40	14.39
1.0	14.37	14.36	14.35	14.34	14.32	14.31	14.30	14.29	14.28	14.27
1.1	14.26	14.24	14.23	14.22	14.21	14.20	14.19	14.18	14.17	14.16
1.2	14.15	14.14	14.13	14.12	14.11	14.10	14.09	14.08	14.07	14.07
1.3	14.06	14.05	14.04	14.03	14.02	14.01	14.00	14.00	13.99	13.98
1.4	13.97	13.96	13.96	13.95	13.94	13.93	13.93	13.92	13.91	13.90
1.5	13.90	13.89	13.88	13.87	13.87	13.86	13.85	13.85	13.84	13.83
1.6	13.83	13.82	13.81	13.81	13.80	13.80	13.79	13.78	13.78	13.77
1.7	13.76	13.76	13.75	13.75	13.74	13.74	13.73	13.72	13.72	13.71
1.8	13.71	13.70	13.70	13.69	13.69	13.68	13.68	13.67	13.66	13.66
1.9	13.65	13.65	13.64	13.64	13.63	13.63	13.63	13.62	13.62	13.61
2.0	13.61	13.60	13.60	13.59	13.59	13.58	13.58	13.57	13.57	13.57
2.1	13.56	13.56	13.55	13.55	13.54	13.54	13.54	13.53	13.53	13.52
2.2	13.52	13.52	13.51	13.51	13.50	13.50	13.50	13.49	13.49	13.48
2.3	13.48	13.48	13.47	13.47	13.46	13.46	13.46	13.45	13.45	13.44
2.4	13.44	13.44	13.43	13.43	13.42	13.42	13.42	13.41	13.41	13.40
2.5	13.40	13.40	13.39	13.39	13.38	13.38	13.38	13.37	13.37	13.36
2.6	13.36	13.36	13.35	13.35	13.34	13.34	13.34	13.33	13.33	13.32
2.7	13.32	13.32	13.31	13.31	13.30	13.30	13.30	13.29	13.29	13.28
2.8	13.28	13.28	13.27	13.27	13.26	13.26	13.26	13.25	13.25	13.24
2.9	13.24	13.24	13.23	13.23	13.22	13.22	13.22	13.21	13.21	13.20
3.0	13.20	13.20	13.19	13.19	13.18	13.18	13.18	13.17	13.17	13.16
3.1	13.16	13.16	13.15	13.15	13.14	13.14	13.14	13.13	13.13	13.12
3.2	13.12	13.12	13.11	13.11	13.10	13.10	13.10	13.09	13.09	13.08
3.3	13.08	13.08	13.07	13.07	13.06	13.06	13.06	13.05	13.05	13.04
3.4	13.04	13.04	13.03	13.03	13.02	13.02	13.02	13.01	13.01	13.00
3.5	13.00	13.00	12.99	12.99	12.98	12.98	12.98	12.97	12.97	12.96
3.6	12.96	12.96	12.95	12.95	12.94	12.94	12.94	12.93	12.93	12.92
3.7	12.92	12.92	12.91	12.91	12.90	12.90	12.90	12.89	12.89	12.88
3.8	12.88	12.88	12.87	12.87	12.86	12.86	12.86	12.85	12.85	12.84
3.9	12.84	12.84	12.83	12.83	12.82	12.82	12.82	12.81	12.81	12.80

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

AIR/FUEL RATIO FROM CARBON MONOXIDE

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
4.0	12.80	12.80	12.79	12.79	12.78	12.78	12.78	12.77	12.77	12.76
4.1	12.76	12.76	12.75	12.75	12.74	12.74	12.74	12.73	12.73	12.72
4.2	12.72	12.72	12.71	12.71	12.70	12.70	12.70	12.69	12.69	12.68
4.3	12.68	12.68	12.67	12.67	12.66	12.66	12.66	12.65	12.65	12.64
4.4	12.64	12.64	12.63	12.63	12.62	12.62	12.62	12.61	12.61	12.60
4.5	12.60	12.60	12.59	12.59	12.58	12.58	12.58	12.57	12.57	12.56
4.6	12.56	12.55	12.55	12.55	12.54	12.54	12.54	12.53	12.53	12.52
4.7	12.52	12.52	12.51	12.51	12.50	12.50	12.50	12.49	12.49	12.48
4.8	12.48	12.48	12.47	12.47	12.46	12.46	12.46	12.45	12.45	12.44
4.9	12.44	12.44	12.43	12.43	12.42	12.42	12.42	12.41	12.41	12.40
5.0	12.40	12.40	12.39	12.39	12.38	12.38	12.38	12.37	12.37	12.36
5.1	12.36	12.36	12.35	12.35	12.34	12.34	12.34	12.33	12.33	12.32
5.2	12.32	12.32	12.31	12.31	12.30	12.30	12.30	12.29	12.29	12.28
5.3	12.28	12.28	12.27	12.27	12.26	12.26	12.26	12.25	12.25	12.24
5.4	12.24	12.24	12.23	12.23	12.22	12.22	12.22	12.21	12.21	12.20
5.5	12.20	12.20	12.19	12.19	12.18	12.18	12.18	12.17	12.17	12.16
5.6	12.16	12.16	12.15	12.15	12.14	12.14	12.14	12.13	12.13	12.12
5.7	12.12	12.12	12.11	12.11	12.10	12.10	12.10	12.09	12.09	12.08
5.8	12.08	12.08	12.07	12.07	12.06	12.06	12.06	12.05	12.05	12.04
5.9	12.04	12.04	12.03	12.03	12.02	12.02	12.02	12.01	12.01	12.00
6.0	12.00	12.00	11.99	11.99	11.98	11.98	11.98	11.97	11.97	11.96
6.1	11.96	11.96	11.95	11.95	11.94	11.94	11.94	11.93	11.93	11.92
6.2	11.92	11.92	11.91	11.91	11.90	11.90	11.90	11.89	11.89	11.88
6.3	11.88	11.88	11.87	11.87	11.86	11.86	11.86	11.85	11.85	11.84
6.4	11.84	11.84	11.83	11.83	11.82	11.82	11.82	11.81	11.81	11.80
6.5	11.80	11.80	11.79	11.79	11.78	11.78	11.78	11.77	11.77	11.76
6.6	11.76	11.76	11.75	11.75	11.74	11.74	11.74	11.73	11.73	11.72
6.7	11.72	11.72	11.71	11.71	11.70	11.70	11.70	11.69	11.69	11.68
6.8	11.68	11.68	11.67	11.67	11.66	11.66	11.66	11.65	11.65	11.64
6.9	11.64	11.64	11.63	11.63	11.62	11.62	11.62	11.61	11.61	11.60
7.0	11.60	11.60	11.59	11.59	11.58	11.58	11.58	11.57	11.57	11.56
7.1	11.56	11.56	11.55	11.55	11.54	11.54	11.54	11.53	11.53	11.52
7.2	11.52	11.52	11.51	11.51	11.50	11.50	11.50	11.49	11.49	11.48
7.3	11.48	11.48	11.47	11.47	11.46	11.46	11.46	11.45	11.45	11.44
7.4	11.44	11.44	11.43	11.43	11.42	11.42	11.42	11.41	11.41	11.40
7.5	11.40	11.40	11.39	11.39	11.38	11.38	11.38	11.37	11.37	11.36
7.6	11.36	11.36	11.35	11.35	11.34	11.34	11.34	11.33	11.33	11.32
7.7	11.32	11.32	11.31	11.31	11.30	11.30	11.30	11.29	11.29	11.28
7.8	11.28	11.28	11.27	11.27	11.26	11.26	11.26	11.25	11.25	11.24
7.9	11.24	11.24	11.23	11.23	11.22	11.22	11.22	11.21	11.21	11.20

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

AIR/FUEL RATIO FROM CARBON MONOXIDE

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
8.0	11.20	11.20	11.19	11.19	11.18	11.18	11.18	11.17	11.17	11.16
8.1	11.16	11.16	11.15	11.15	11.14	11.14	11.14	11.13	11.13	11.12
8.2	11.12	11.12	11.11	11.11	11.10	11.10	11.10	11.09	11.09	11.08
8.3	11.08	11.08	11.07	11.07	11.06	11.06	11.06	11.05	11.05	11.04
8.4	11.04	11.04	11.03	11.03	11.02	11.02	11.02	11.01	11.01	11.00
8.5	11.00	11.00	10.99	10.99	10.98	10.98	10.98	10.97	10.97	10.96
8.6	10.96	10.96	10.95	10.95	10.94	10.94	10.94	10.93	10.93	10.92
8.7	10.92	10.92	10.91	10.91	10.90	10.90	10.90	10.89	10.89	10.88
8.8	10.88	10.88	10.87	10.87	10.86	10.86	10.86	10.85	10.85	10.84
8.9	10.84	10.84	10.83	10.83	10.82	10.82	10.82	10.81	10.81	10.80
9.0	10.80	10.80	10.79	10.79	10.78	10.78	10.78	10.77	10.77	10.76
9.1	10.76	10.76	10.75	10.75	10.74	10.74	10.74	10.73	10.73	10.72
9.2	10.72	10.72	10.71	10.71	10.70	10.70	10.70	10.69	10.69	10.68
9.3	10.68	10.68	10.67	10.67	10.66	10.66	10.66	10.65	10.65	10.64
9.4	10.64	10.64	10.63	10.63	10.62	10.62	10.62	10.61	10.61	10.60
9.5	10.60	10.60	10.59	10.59	10.58	10.58	10.58	10.57	10.57	10.56
9.6	10.56	10.56	10.55	10.55	10.54	10.54	10.54	10.53	10.53	10.52
9.7	10.52	10.52	10.51	10.51	10.50	10.50	10.50	10.49	10.49	10.48
9.8	10.48	10.48	10.47	10.47	10.46	10.46	10.46	10.45	10.45	10.44
9.9	10.44	10.44	10.43	10.43	10.42	10.42	10.42	10.41	10.41	10.40
10.0	10.40	10.40	10.39	10.39	10.38	10.38	10.38	10.37	10.37	10.36
10.1	10.36	10.36	10.35	10.35	10.34	10.34	10.34	10.33	10.33	10.32
10.2	10.32	10.32	10.31	10.31	10.30	10.30	10.30	10.29	10.29	10.28
10.3	10.28	10.28	10.27	10.27	10.26	10.26	10.26	10.25	10.25	10.24
10.4	10.24	10.24	10.23	10.23	10.22	10.22	10.22	10.21	10.21	10.20
10.5	10.20	10.20	10.19	10.19	10.18	10.18	10.18	10.17	10.17	10.16
10.6	10.16	10.16	10.15	10.15	10.14	10.14	10.14	10.13	10.13	10.12
10.7	10.12	10.12	10.11	10.11	10.10	10.10	10.10	10.09	10.09	10.08
10.8	10.08	10.08	10.07	10.07	10.06	10.06	10.06	10.05	10.05	10.04
10.9	10.04	10.04	10.03	10.03	10.02	10.02	10.02	10.01	10.01	10.00
11.0	10.00	10.00	9.99	9.99	9.98	9.98	9.98	9.97	9.97	9.96
11.1	9.96	9.96	9.95	9.95	9.94	9.94	9.94	9.93	9.93	9.92
11.2	9.92	9.92	9.91	9.91	9.90	9.90	9.90	9.89	9.89	9.88
11.3	9.88	9.88	9.87	9.87	9.86	9.86	9.86	9.85	9.85	9.84
11.4	9.84	9.84	9.83	9.83	9.82	9.82	9.82	9.81	9.81	9.80
11.5	9.80	9.80	9.79	9.79	9.78	9.78	9.78	9.77	9.77	9.76
11.6	9.76	9.76	9.75	9.75	9.74	9.74	9.74	9.73	9.73	9.72
11.7	9.72	9.72	9.71	9.71	9.70	9.70	9.70	9.69	9.69	9.68
11.8	9.68	9.68	9.67	9.67	9.66	9.66	9.66	9.65	9.65	9.64
11.9	9.64	9.64	9.63	9.63	9.62	9.62	9.62	9.61	9.61	9.60

AIR/FUEL RATIO FROM CARBON MONOXIDE

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
12.0	9.60	9.60	9.59	9.59	9.58	9.58	9.58	9.57	9.57	9.56
12.1	9.56	9.56	9.55	9.55	9.54	9.54	9.54	9.53	9.53	9.52
12.2	9.52	9.52	9.51	9.51	9.50	9.50	9.50	9.49	9.49	9.48
12.3	9.48	9.48	9.47	9.47	9.46	9.46	9.46	9.45	9.45	9.44
12.4	9.44	9.44	9.43	9.43	9.42	9.42	9.42	9.41	9.41	9.40
12.5	9.40	9.40	9.39	9.39	9.38	9.38	9.38	9.37	9.37	9.36
12.6	9.36	9.36	9.35	9.35	9.34	9.34	9.34	9.33	9.33	9.32
12.7	9.32	9.32	9.31	9.31	9.30	9.30	9.30	9.29	9.29	9.28
12.8	9.28	9.28	9.27	9.27	9.26	9.26	9.26	9.25	9.25	9.24
12.9	9.24	9.24	9.23	9.23	9.22	9.22	9.22	9.21	9.21	9.20
13.0	9.20	9.20	9.19	9.19	9.18	9.18	9.18	9.17	9.17	9.16
13.1	9.16	9.16	9.15	9.15	9.14	9.14	9.14	9.13	9.13	9.12
13.2	9.12	9.12	9.11	9.11	9.10	9.10	9.10	9.09	9.09	9.08
13.3	9.08	9.08	9.07	9.07	9.06	9.06	9.06	9.05	9.05	9.04
13.4	9.04	9.04	9.03	9.03	9.02	9.02	9.02	9.01	9.01	9.00
13.5	9.00	9.00	8.99	8.99	8.98	8.98	8.98	8.97	8.97	8.96
13.6	8.96	8.96	8.95	8.95	8.94	8.94	8.94	8.93	8.93	8.92
13.7	8.92	8.92	8.91	8.91	8.90	8.90	8.90	8.89	8.89	8.88
13.8	8.88	8.88	8.87	8.87	8.86	8.86	8.86	8.85	8.85	8.84
13.9	8.84	8.84	8.83	8.83	8.82	8.82	8.82	8.81	8.81	8.80
14.0	8.80	8.80	8.79	8.79	8.78	8.78	8.78	8.77	8.77	8.76
14.1	8.76	8.76	8.75	8.75	8.74	8.74	8.74	8.73	8.73	8.72
14.2	8.72	8.72	8.71	8.71	8.70	8.70	8.70	8.69	8.69	8.68
14.3	8.68	8.68	8.67	8.67	8.66	8.66	8.66	8.65	8.65	8.64
14.4	8.64	8.64	8.63	8.63	8.62	8.62	8.62	8.61	8.61	8.60
14.5	8.60	8.60	8.59	8.59	8.58	8.58	8.58	8.57	8.57	8.56
14.6	8.56	8.56	8.55	8.55	8.54	8.54	8.54	8.53	8.53	8.52
14.7	8.52	8.52	8.51	8.51	8.50	8.50	8.50	8.49	8.49	8.48
14.8	8.48	8.48	8.47	8.47	8.46	8.46	8.46	8.45	8.45	8.44
14.9	8.44	8.44	8.43	8.43	8.42	8.42	8.42	8.41	8.41	8.40
15.0	8.40	8.40	8.39	8.39	8.38	8.38	8.38	8.37	8.37	8.36
15.1	8.36	8.36	8.35	8.35	8.34	8.34	8.34	8.33	8.33	8.32
15.2	8.32	8.32	8.31	8.31	8.30	8.30	9.30	8.29	8.29	8.28
15.3	8.28	8.28	8.27	8.27	8.26	8.26	8.26	8.25	8.25	8.24
15.4	8.24	8.24	8.23	8.23	8.22	8.22	8.22	8.21	8.21	8.20
15.5	8.20	8.20	8.19	8.19	8.18	8.18	8.18	8.17	8.17	8.16
15.6	8.16	8.16	8.15	8.15	8.14	8.14	8.14	8.13	8.13	8.12
15.7	8.12	8.12	8.11	8.11	8.10	8.10	8.10	8.09	8.09	8.08
15.8	8.08	8.08	8.07	8.07	8.06	8.06	8.06	8.05	8.05	8.04
15.9	8.04	8.04	8.03	8.03	8.02	8.02	8.02	8.01	8.01	8.00

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

AIR/FUEL RATIO FROM CARBON DIOXIDE...RICH

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
4.0	7.75	7.76	7.76	7.77	7.78	7.78	7.79	7.79	7.80	7.81
4.1	7.81	7.82	7.83	7.83	7.84	7.84	7.85	7.86	7.86	7.87
4.2	7.88	7.88	7.89	7.89	7.90	7.91	7.91	7.92	7.93	7.93
4.3	7.94	7.94	7.95	7.96	7.96	7.97	7.98	7.98	7.99	7.99
4.4	8.00	8.01	8.01	8.02	8.03	8.03	8.04	8.04	8.05	8.06
4.5	8.06	8.07	8.08	8.08	8.09	8.09	8.10	8.11	8.11	8.12
4.6	8.13	8.13	8.14	8.14	8.15	8.16	8.16	8.17	8.18	8.18
4.7	8.19	8.19	8.20	8.21	8.21	8.22	8.23	8.23	8.24	8.24
4.8	8.25	8.26	8.26	8.27	8.28	8.28	8.29	8.29	8.30	8.31
4.9	8.31	8.32	8.33	8.33	8.34	8.34	8.35	8.36	8.36	8.37
5.0	8.38	8.38	8.39	8.39	8.40	8.41	8.41	8.42	8.43	8.43
5.1	8.44	8.44	8.45	8.46	8.46	8.47	8.48	8.48	8.49	8.49
5.2	8.50	8.51	8.51	8.52	8.53	8.53	8.54	8.54	8.55	8.56
5.3	8.56	8.57	8.58	8.58	8.59	8.59	8.60	8.61	8.61	8.62
5.4	8.63	8.63	8.64	8.64	8.65	8.66	8.66	8.67	8.68	8.68
5.5	8.69	8.69	8.70	8.71	8.71	8.72	8.73	8.73	8.74	8.74
5.6	8.75	8.76	8.76	8.77	8.78	8.78	8.79	8.79	8.80	8.81
5.7	8.81	8.82	8.83	8.83	8.84	8.84	8.85	8.86	8.86	8.87
5.8	8.88	8.88	8.89	8.89	8.90	8.91	8.91	8.92	8.93	8.93
5.9	8.94	8.94	8.95	8.96	8.96	8.97	8.98	8.98	8.99	8.99
6.0	9.00	9.01	9.01	9.02	9.03	9.03	9.04	9.04	9.05	9.06
6.1	9.06	9.07	9.08	9.08	9.09	9.09	9.10	9.11	9.11	9.12
6.2	9.13	9.13	9.14	9.14	9.15	9.16	9.16	9.17	9.18	9.18
6.3	9.19	9.19	9.20	9.21	9.21	9.22	9.23	9.23	9.24	9.24
6.4	9.25	9.26	9.26	9.27	9.28	9.28	9.29	9.29	9.30	9.31
6.5	9.31	9.32	9.33	9.33	9.34	9.34	9.35	9.36	9.36	9.37
6.6	9.38	9.38	9.39	9.39	9.40	9.41	9.41	9.42	9.43	9.43
6.7	9.44	9.44	9.45	9.46	9.46	9.47	9.48	9.48	9.49	9.49
6.8	9.50	9.51	9.51	9.52	9.53	9.53	9.54	9.54	9.55	9.56
6.9	9.56	9.57	9.58	9.58	9.59	9.59	9.60	9.61	9.61	9.62
7.0	9.63	9.63	9.64	9.64	9.65	9.66	9.66	9.67	9.68	9.68
7.1	9.69	9.69	9.70	9.71	9.71	9.72	9.73	9.73	9.74	9.74
7.2	9.75	9.76	9.76	9.77	9.78	9.78	9.79	9.79	9.80	9.81
7.3	9.81	9.82	9.83	9.83	9.84	9.84	9.85	9.86	9.86	9.87
7.4	9.88	9.88	9.89	9.89	9.90	9.91	9.91	9.92	9.93	9.93
7.5	9.94	9.94	9.95	9.96	9.96	9.97	9.98	9.98	9.99	9.99
7.6	10.00	10.01	10.01	10.02	10.03	10.03	10.04	10.04	10.05	10.06
7.7	10.06	10.07	10.08	10.08	10.09	10.09	10.10	10.11	10.11	10.12
7.8	10.13	10.13	10.14	10.14	10.15	10.16	10.16	10.17	10.18	10.18
7.9	10.19	10.19	10.20	10.21	10.21	10.22	10.23	10.23	10.24	10.24

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

AIR/FUEL RATIO FROM CARBON DIOXIDE...RICH

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
8.0	10.25	10.26	10.26	10.27	10.28	10.28	10.29	10.29	10.30	10.31
8.1	10.31	10.32	10.33	10.33	10.34	10.34	10.35	10.36	10.36	10.37
8.2	10.38	10.38	10.39	10.39	10.40	10.41	10.41	10.42	10.43	10.43
8.3	10.44	10.44	10.45	10.46	10.46	10.47	10.48	10.48	10.49	10.49
8.4	10.50	10.51	10.51	10.52	10.53	10.53	10.54	10.54	10.55	10.56
8.5	10.56	10.57	10.58	10.58	10.59	10.59	10.60	10.61	10.61	10.62
8.6	10.63	10.63	10.64	10.64	10.65	10.66	10.66	10.67	10.68	10.68
8.7	10.69	10.69	10.70	10.71	10.71	10.72	10.73	10.73	10.74	10.74
8.8	10.75	10.76	10.76	10.77	10.78	10.78	10.79	10.79	10.80	10.81
8.9	10.81	10.82	10.83	10.83	10.84	10.84	10.85	10.86	10.86	10.87
9.0	10.88	10.88	10.89	10.89	10.90	10.91	10.91	10.92	10.93	10.93
9.1	10.94	10.94	10.95	10.96	10.96	10.97	10.98	10.98	10.99	10.99
9.2	11.00	11.01	11.01	11.02	11.03	11.03	11.04	11.04	11.05	11.06
9.3	11.06	11.07	11.08	11.08	11.09	11.09	11.10	11.11	11.11	11.12
9.4	11.13	11.13	11.14	11.14	11.15	11.16	11.16	11.17	11.18	11.18
9.5	11.19	11.19	11.20	11.21	11.21	11.22	11.23	11.23	11.24	11.24
9.6	11.25	11.26	11.26	11.27	11.28	11.28	11.29	11.29	11.30	11.31
9.7	11.31	11.32	11.33	11.33	11.34	11.34	11.35	11.36	11.36	11.37
9.8	11.38	11.38	11.39	11.39	11.40	11.41	11.41	11.42	11.43	11.43
9.9	11.44	11.44	11.45	11.46	11.46	11.47	11.48	11.48	11.49	11.49
10.0	11.50	11.51	11.51	11.52	11.53	11.53	11.54	11.54	11.55	11.56
10.1	11.56	11.57	11.58	11.58	11.59	11.59	11.60	11.61	11.61	11.62
10.2	11.63	11.63	11.64	11.64	11.65	11.66	11.66	11.67	11.68	11.68
10.3	11.69	11.69	11.70	11.71	11.71	11.72	11.73	11.73	11.74	11.74
10.4	11.75	11.76	11.76	11.77	11.78	11.78	11.79	11.79	11.80	11.81
10.5	11.81	11.82	11.83	11.83	11.84	11.84	11.85	11.86	11.66	11.87
10.6	11.88	11.88	11.89	11.89	11.90	11.91	11.91	11.92	11.93	11.93
10.7	11.94	11.94	11.95	11.96	11.96	11.97	11.98	11.98	11.99	11.99
10.8	12.00	12.01	12.01	12.02	12.03	12.03	12.04	12.04	12.05	12.06
10.9	12.06	12.07	12.08	12.08	12.09	12.09	12.10	12.11	12.11	12.12
11.0	12.13	12.13	12.14	12.14	12.15	12.16	12.16	12.17	12.18	12.18
11.1	12.19	12.19	12.20	12.21	12.21	12.22	12.23	12.23	12.24	12.24
11.2	12.25	12.26	12.26	12.27	12.28	12.28	12.29	12.29	12.30	12.31
11.3	12.31	12.32	12.33	12.33	12.34	12.34	12.35	12.36	12.36	12.37
11.4	12.38	12.38	12.39	12.39	12.40	12.41	12.41	12.42	12.43	12.43
11.5	12.44	12.44	12.45	12.46	12.46	12.47	12.48	12.48	12.49	12.49
11.6	12.50	12.51	12.51	12.52	12.53	12.53	12.54	12.54	12.55	12.56
11.7	12.56	12.57	12.58	12.58	12.59	12.59	12.60	12.61	12.61	12.62
11.8	12.63	12.63	12.64	12.64	12.65	12.66	12.66	12.67	12.68	12.68
11.9	12.69	12.69	12.70	12.71	12.71	12.72	12.73	12.73	12.74	12.74

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

AIR/FUEL RATIO FROM CARBON DIOXIDE...RICH

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
12.0	12.75	12.76	12.76	12.77	12.78	12.78	12.79	12.79	12.80	12.81
12.1	12.81	12.82	12.83	12.83	12.84	12.84	12.85	12.86	12.86	12.87
12.2	12.88	12.88	12.89	12.89	12.90	12.91	12.91	12.92	12.93	12.93
12.3	12.94	12.94	12.95	12.96	12.96	12.97	12.98	12.98	12.99	12.99
12.4	13.00	13.01	13.01	13.02	13.03	13.03	13.04	13.04	13.05	13.06
12.5	13.06	13.07	13.08	13.08	13.09	13.09	13.10	13.11	13.11	13.12
12.6	13.13	13.13	13.14	13.14	13.15	13.16	13.16	13.17	13.18	13.18
12.7	13.19	13.19	13.20	13.21	13.21	13.22	13.23	13.23	13.24	13.24
12.8	13.25	13.26	13.26	13.27	13.28	13.28	13.29	13.29	13.30	13.31
12.9	13.31	13.32	13.33	13.33	13.34	13.34	13.35	13.36	13.36	13.37
13.0	13.38	13.38	13.39	13.39	13.40	13.41	13.42	13.42	13.43	13.44
13.1	13.45	13.46	13.46	13.47	13.48	13.49	13.50	13.51	13.52	13.53
13.2	13.54	13.55	13.57	13.58	13.59	13.60	13.62	13.63	13.65	13.66
13.3	13.68	13.69	13.71	13.73	13.75	13.77	13.79	13.81	13.83	13.85
13.4	13.88	13.90	13.93	13.96	13.99	14.02	14.06	14.09	14.13	14.17

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

AIR/FUEL RATIO FROM CARBON DIOXIDE...LEAN

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
11.0	19.40	19.38	19.36	19.34	19.32	19.30	19.28	19.26	19.24	19.22
11.1	19.20	19.18	19.16	19.14	19.12	19.10	19.08	19.06	19.04	19.02
11.2	19.00	18.98	18.96	18.94	18.92	18.90	18.88	18.86	18.84	18.82
11.3	18.80	18.78	18.76	18.74	18.72	18.70	18.68	18.66	18.64	18.62
11.4	18.60	18.58	18.56	18.54	18.52	18.50	18.48	18.46	18.44	18.42
11.5	18.40	18.38	18.36	18.34	18.32	18.30	18.28	18.26	18.24	18.22
11.6	18.20	18.18	18.16	18.14	18.12	18.10	18.08	18.06	18.04	18.02
11.7	18.00	17.98	17.96	17.94	17.92	17.90	17.88	17.86	17.84	17.82
11.8	17.80	17.78	17.76	17.74	17.72	17.70	17.68	17.66	17.64	17.62
11.9	17.60	17.58	17.56	17.54	17.52	17.50	17.48	17.46	17.44	17.42
12.0	17.40	17.38	17.36	17.34	17.32	17.30	17.28	17.26	17.24	17.22
12.1	17.20	17.18	17.16	17.14	17.12	17.10	17.08	17.06	17.04	17.02
12.2	17.00	16.98	16.96	16.94	16.92	16.90	16.88	16.86	16.84	16.82
12.3	16.80	16.78	16.76	16.74	16.72	16.70	16.68	16.66	16.64	16.62
12.4	16.60	16.58	16.56	16.54	16.52	16.50	16.48	16.46	16.44	16.42
12.5	16.40	16.38	16.36	16.34	16.32	16.30	16.28	16.26	16.24	16.22
12.6	16.20	16.18	16.16	16.14	16.12	16.10	16.08	16.06	16.04	16.02
12.7	16.00	15.98	15.96	15.94	15.92	15.90	15.88	15.86	15.84	15.82
12.8	15.80	15.78	15.76	15.74	15.72	15.70	15.68	15.66	15.64	15.62
12.9	15.60	15.58	15.56	15.54	15.52	15.50	15.48	15.46	15.44	15.42
13.0	15.40	15.38	15.36	15.34	15.32	15.30	15.28	15.26	15.24	15.22
13.1	15.20	15.18	15.16	15.14	15.12	15.10	15.08	15.06	15.04	15.02
13.2	15.00	14.98	14.96	14.94	14.92	14.90	14.88	14.86	14.84	14.82
13.3	14.80	14.78	14.76	14.73	14.71	14.69	14.66	14.63	14.60	14.57
13.4	14.53	14.49	14.45	14.41	14.36	14.31	14.26	14.20	14.13	14.06

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.00	11.700	11.760	11.817	11.873	11.927	11.979	12.030	12.079	12.126	12.172
.01	12.216	12.259	12.301	12.341	12.380	12.417	12.454	12.489	12.524	12.557
.02	12.589	12.620	12.651	12.680	12.709	12.737	12.764	12.790	12.816	12.841
.03	12.865	12.888	12.911	12.934	12.955	12.977	12.997	13.017	13.037	13.056
.04	13.075	13.093	13.110	13.128	13.145	13.161	13.177	13.193	13.208	13.223
.05	13.238	13.253	13.267	13.280	13.294	13.307	13.319	13.330	13.340	13.349
.06	13.358	13.366	13.374	13.381	13.387	13.394	13.399	13.405	13.410	13.415
.07	13.420	13.424	13.428	13.432	13.436	13.440	13.443	13.446	13.450	13.453
.08	13.455	13.458	13.461	13.463	13.466	13.468	13.471	13.473	13.475	13.477
.09	13.479	13.478	13.475	13.472	13.469	13.465	13.462	13.459	13.455	13.452
.10	13.448	13.445	13.442	13.438	13.435	13.431	13.428	13.424	13.421	13.417
.11	13.414	13.410	13.406	13.403	13.399	13.396	13.392	13.388	13.385	13.381
.12	13.377	13.373	13.370	13.366	13.362	13.358	13.354	13.350	13.346	13.343
.13	13.339	13.335	13.331	13.327	13.323	13.319	13.315	13.311	13.307	13.302
.14	13.298	13.294	13.290	13.286	13.282	13.277	13.273	13.269	13.265	13.260
.15	13.256	13.251	13.247	13.243	13.238	13.234	13.229	13.225	13.220	13.216
.16	13.211	13.207	13.202	13.197	13.193	13.188	13.183	13.179	13.174	13.169
.17	13.164	13.159	13.154	13.149	13.144	13.138	13.133	13.128	13.122	13.117
.18	13.111	13.105	13.099	13.093	13.087	13.081	13.075	13.069	13.063	13.056
.19	13.050	13.043	13.036	13.029	13.022	13.015	13.008	13.001	12.993	12.986
.20	12.979	12.971	12.964	12.957	12.949	12.942	12.935	12.927	12.920	12.913
.21	12.906	12.898	12.891	12.884	12.876	12.869	12.862	12.855	12.848	12.840
.22	12.833	12.826	12.819	12.812	12.804	12.797	12.790	12.783	12.776	12.769
.23	12.762	12.754	12.747	12.740	12.733	12.726	12.719	12.712	12.705	12.698
.24	12.691	12.684	12.677	12.670	12.663	12.656	12.649	12.642	12.635	12.628
.25	12.621	12.614	12.607	12.600	12.593	12.586	12.579	12.572	12.565	12.558
.26	12.551	12.545	12.538	12.531	12.524	12.517	12.510	12.503	12.497	12.490
.27	12.483	12.476	12.469	12.463	12.456	12.449	12.442	12.435	12.429	12.422
.28	12.415	12.408	12.402	12.395	12.388	12.382	12.375	12.368	12.362	12.355
.29	12.348	12.342	12.335	12.328	12.322	12.315	12.308	12.302	12.295	12.288
.30	12.282	12.275	12.269	12.262	12.256	12.249	12.242	12.236	12.229	12.223
.31	12.216	12.210	12.203	12.197	12.190	12.184	12.177	12.171	12.164	12.158
.32	12.151	12.145	12.138	12.132	12.126	12.119	12.113	12.106	12.100	12.094
.33	12.087	12.081	12.074	12.068	12.062	12.055	12.049	12.043	12.036	12.030
.34	12.024	12.017	12.011	12.005	11.998	11.992	11.986	11.980	11.973	11.967
.35	11.961	11.955	11.948	11.942	11.936	11.930	11.923	11.917	11.911	11.905
.36	11.899	11.892	11.886	11.880	11.874	11.868	11.862	11.855	11.849	11.843
.37	11.837	11.831	11.825	11.819	11.813	11.806	11.800	11.794	11.788	11.782
.38	11.776	11.770	11.764	11.758	11.752	11.746	11.740	11.734	11.728	11.722
.39	11.716	11.710	11.704	11.698	11.692	11.686	11.680	11.674	11.668	11.662

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.40	11.656	11.650	11.644	11.638	11.632	11.626	11.621	11.615	11.609	11.603
.41	11.597	11.591	11.585	11.579	11.573	11.568	11.562	11.556	11.550	11.544
.42	11.538	11.533	11.527	11.521	11.515	11.509	11.504	11.498	11.492	11.486
.43	11.481	11.475	11.469	11.463	11.458	11.452	11.446	11.440	11.435	11.429
.44	11.423	11.418	11.412	11.406	11.400	11.395	11.389	11.383	11.378	11.372
.45	11.366	11.361	11.355	11.350	11.344	11.338	11.333	11.327	11.321	11.316
.46	11.310	11.305	11.299	11.294	11.288	11.282	11.277	11.271	11.266	11.260
.47	11.255	11.249	11.244	11.238	11.233	11.227	11.221	11.216	11.210	11.205
.48	11.200	11.194	11.189	11.183	11.178	11.172	11.167	11.161	11.156	11.150
.49	11.145	11.140	11.134	11.129	11.123	11.118	11.112	11.107	11.102	11.096
.50	11.091	11.086	11.080	11.075	11.069	11.064	11.059	11.053	11.048	11.043
.51	11.037	11.032	11.027	11.021	11.016	11.011	11.006	11.000	10.995	10.990
.52	10.984	10.979	10.974	10.969	10.963	10.958	10.953	10.948	10.942	10.937
.53	10.932	10.927	10.921	10.916	10.911	10.906	10.901	10.895	10.890	10.885
.54	10.880	10.875	10.870	10.864	10.859	10.854	10.849	10.844	10.839	10.834
.55	10.828	10.823	10.818	10.813	10.808	10.803	10.798	10.793	10.788	10.782
.56	10.777	10.772	10.767	10.762	10.757	10.752	10.747	10.742	10.737	10.732
.57	10.727	10.722	10.717	10.712	10.707	10.702	10.697	10.692	10.687	10.682
.58	10.677	10.672	10.667	10.662	10.657	10.652	10.647	10.642	10.637	10.632
.59	10.627	10.622	10.617	10.612	10.607	10.603	10.598	10.593	10.588	10.583
.60	10.578	10.573	10.568	10.563	10.559	10.554	10.549	10.544	10.539	10.534
.61	10.529	10.524	10.520	10.515	10.510	10.505	10.500	10.496	10.491	10.486
.62	10.481	10.476	10.472	10.467	10.462	10.457	10.452	10.448	10.443	10.438
.63	10.433	10.429	10.424	10.419	10.414	10.410	10.405	10.400	10.395	10.391
.64	10.386	10.381	10.377	10.372	10.367	10.362	10.358	10.353	10.348	10.344
.65	10.339	10.334	10.330	10.325	10.320	10.316	10.311	10.306	10.302	10.297
.66	10.292	10.288	10.283	10.279	10.274	10.269	10.265	10.260	10.256	10.251
.67	10.246	10.242	10.237	10.233	10.228	10.223	10.219	10.214	10.210	10.205
.68	10.201	10.196	10.192	10.187	10.183	10.178	10.173	10.169	10.164	10.160
.69	10.155	10.151	10.146	10.142	10.137	10.133	10.128	10.124	10.119	10.115
.70	10.110	10.106	10.102	10.097	10.093	10.088	10.084	10.079	10.075	10.070
.71	10.066	10.062	10.057	10.053	10.048	10.044	10.039	10.035	10.031	10.026
.72	10.022	10.018	10.013	10.009	10.004	10.000	9.996	9.991	9.987	9.983
.73	9.978	9.974	9.969	9.965	9.961	9.956	9.952	9.948	9.943	9.939
.74	9.935	9.931	9.926	9.922	9.918	9.913	9.909	9.905	9.900	9.896
.75	9.892	9.888	9.883	9.879	9.875	9.871	9.866	9.862	9.858	9.854
.76	9.849	9.845	9.841	9.837	9.832	9.828	9.824	9.820	9.815	9.811
.77	9.807	9.803	9.799	9.794	9.790	9.786	9.782	9.778	9.774	9.769
.78	9.765	9.761	9.757	9.753	9.749	9.744	9.740	9.736	9.732	9.728
.79	9.724	9.720	9.715	9.711	9.707	9.703	9.699	9.695	9.691	9.687

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.80	9.683	9.678	9.674	9.670	9.666	9.662	9.658	9.654	9.650	9.646
.81	9.642	9.638	9.634	9.630	9.625	9.621	9.617	9.613	9.609	9.605
.82	9.601	9.597	9.593	9.589	9.585	9.581	9.577	9.573	9.569	9.565
.83	9.561	9.557	9.553	9.549	9.545	9.541	9.537	9.533	9.529	9.525
.84	9.521	9.517	9.513	9.509	9.506	9.502	9.498	9.494	9.490	9.486
.85	9.482	9.478	9.474	9.470	9.466	9.462	9.458	9.454	9.451	9.447
.86	9.443	9.439	9.435	9.431	9.427	9.423	9.419	9.416	9.412	9.408
.87	9.404	9.400	9.396	9.392	9.388	9.385	9.381	9.377	9.373	9.369
.88	9.365	9.362	9.358	9.354	9.350	9.346	9.342	9.339	9.335	9.331
.89	9.327	9.323	9.320	9.316	9.312	9.308	9.304	9.301	9.297	9.293
.90	9.289	9.286	9.282	9.278	9.274	9.271	9.267	9.263	9.259	9.256
.91	9.252	9.248	9.244	9.241	9.237	9.233	9.229	9.226	9.222	9.218
.92	9.215	9.211	9.207	9.203	9.200	9.196	9.192	9.189	9.185	9.181
.93	9.178	9.174	9.170	9.166	9.163	9.159	9.155	9.152	9.148	9.145
.94	9.141	9.137	9.134	9.130	9.126	9.123	9.119	9.115	9.112	9.108
.95	9.104	9.101	9.097	9.094	9.090	9.086	9.083	9.079	9.076	9.072
.96	9.068	9.065	9.061	9.058	9.054	9.050	9.047	9.043	9.040	9.036
.97	9.033	9.029	9.025	9.022	9.018	9.015	9.011	9.008	9.004	9.001
.98	8.997	8.994	8.990	8.986	8.983	8.979	8.976	8.972	8.969	8.965
.99	8.962	8.958	8.955	8.951	8.948	8.944	8.941	8.937	8.934	8.930
1.00	8.927	8.923	8.920	8.916	8.913	8.909	8.906	8.903	8.899	8.896
1.01	8.892	8.889	8.885	8.882	8.878	8.875	8.871	8.868	8.865	8.861
1.02	8.858	8.854	8.851	8.847	8.844	8.841	8.837	8.834	8.830	8.827
1.03	8.824	8.820	8.817	8.813	8.810	8.807	8.803	8.800	8.796	8.793
1.04	8.790	8.786	8.783	8.780	8.776	8.773	8.769	8.766	8.763	8.759
1.05	8.756	8.753	8.749	8.746	8.743	8.739	8.736	8.733	8.729	8.726
1.06	8.723	8.719	8.716	8.713	8.709	8.706	8.703	8.699	8.696	8.693
1.07	8.689	8.686	8.683	8.680	8.676	8.673	8.670	8.666	8.663	8.660
1.08	8.657	8.653	8.650	8.647	8.643	8.640	8.637	8.634	8.630	8.627
1.09	8.624	8.621	8.617	8.614	8.611	8.608	8.604	8.601	8.598	8.595
1.10	8.592	8.588	8.585	8.582	8.579	8.575	8.572	8.569	8.566	8.563
1.11	8.559	8.556	8.553	8.550	8.547	8.543	8.540	8.537	8.534	8.531
1.12	8.527	8.524	8.521	8.518	8.515	8.512	8.508	8.505	8.502	8.499
1.13	8.496	8.493	8.490	8.486	8.483	8.480	8.477	8.474	8.471	8.468
1.14	8.464	8.461	8.458	8.455	8.452	8.449	8.446	8.443	8.439	8.436
1.15	8.433	8.430	8.427	8.424	8.421	8.418	8.415	8.411	8.408	8.405
1.16	8.402	8.399	8.396	8.393	8.390	8.387	8.384	8.381	8.378	8.375
1.17	8.371	8.368	8.365	8.362	8.359	8.356	8.353	8.350	8.347	8.344
1.18	8.341	8.338	8.335	8.332	8.329	8.326	8.323	8.320	8.317	8.314
1.19	8.311	8.308	8.305	8.302	8.299	8.296	8.293	8.290	8.287	8.284

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.20	8.281	8.278	8.275	8.272	8.269	8.266	8.263	8.260	8.257	8.254
1.21	8.251	8.248	8.245	8.242	8.239	8.236	8.233	8.230	8.227	8.224
1.22	8.221	8.218	8.215	8.212	8.209	8.206	8.203	8.200	8.197	8.195
1.23	8.192	8.189	8.186	8.183	8.180	8.177	8.174	8.171	8.168	8.165
1.24	8.162	8.159	8.157	8.154	8.151	8.148	8.145	8.142	8.139	8.136
1.25	8.133	8.130	8.128	8.125	8.122	8.119	8.116	8.113	8.110	8.107
1.26	8.105	8.102	8.099	8.096	8.093	8.090	8.087	8.084	8.082	8.079
1.27	8.076	8.073	8.070	8.067	8.065	8.062	8.059	8.056	8.053	8.050
1.28	8.047	8.045	8.042	8.039	8.036	8.033	8.031	8.028	8.025	8.022
1.29	8.019	8.016	8.014	8.011	8.008	8.005	8.002	8.000	7.997	7.994
1.30	7.991	7.988	7.986	7.983	7.980	7.977	7.975	7.972	7.969	7.966
1.31	7.963	7.961	7.958	7.955	7.952	7.950	7.947	7.944	7.941	7.939
1.32	7.936	7.933	7.930	7.928	7.925	7.922	7.919	7.917	7.914	7.911
1.33	7.908	7.906	7.903	7.900	7.897	7.895	7.892	7.889	7.887	7.884
1.34	7.881	7.878	7.876	7.873	7.870	7.868	7.865	7.862	7.859	7.857
1.35	7.854	7.851	7.849	7.846	7.843	7.841	7.838	7.835	7.833	7.830
1.36	7.827	7.825	7.822	7.819	7.817	7.814	7.811	7.808	7.806	7.803
1.37	7.801	7.798	7.795	7.793	7.790	7.787	7.785	7.782	7.779	7.777
1.38	7.774	7.771	7.769	7.766	7.763	7.761	7.758	7.756	7.753	7.750
1.39	7.748	7.745	7.742	7.740	7.737	7.735	7.732	7.729	7.727	7.724
1.40	7.722	7.719	7.716	7.714	7.711	7.709	7.706	7.703	7.701	7.698
1.41	7.696	7.693	7.690	7.688	7.685	7.683	7.680	7.677	7.675	7.672
1.42	7.670	7.667	7.665	7.662	7.659	7.657	7.654	7.652	7.649	7.647
1.43	7.644	7.642	7.639	7.636	7.634	7.631	7.629	7.626	7.624	7.621
1.44	7.619	7.616	7.614	7.611	7.609	7.606	7.603	7.601	7.598	7.596
1.45	7.593	7.591	7.588	7.586	7.583	7.581	7.578	7.576	7.573	7.571
1.46	7.568	7.566	7.563	7.561	7.558	7.556	7.553	7.551	7.548	7.546
1.47	7.543	7.541	7.538	7.536	7.533	7.531	7.528	7.526	7.523	7.521
1.48	7.518	7.516	7.514	7.511	7.509	7.506	7.504	7.501	7.499	7.496
1.49	7.494	7.491	7.489	7.486	7.484	7.482	7.479	7.477	7.474	7.472
1.50	7.469	7.467	7.465	7.462	7.460	7.457	7.455	7.452	7.450	7.448
1.51	7.445	7.443	7.440	7.438	7.435	7.433	7.431	7.428	7.426	7.423
1.52	7.421	7.419	7.416	7.414	7.411	7.409	7.407	7.404	7.402	7.399
1.53	7.397	7.395	7.392	7.390	7.387	7.385	7.383	7.380	7.378	7.375
1.54	7.373	7.371	7.368	7.366	7.364	7.361	7.359	7.356	7.354	7.352
1.55	7.349	7.347	7.345	7.342	7.340	7.338	7.335	7.333	7.331	7.328
1.56	7.326	7.324	7.321	7.319	7.316	7.314	7.312	7.309	7.307	7.305
1.57	7.302	7.300	7.298	7.295	7.293	7.291	7.289	7.286	7.284	7.282
1.58	7.279	7.277	7.275	7.272	7.270	7.268	7.265	7.263	7.261	7.258
1.59	7.256	7.254	7.252	7.249	7.247	7.245	7.242	7.240	7.238	7.235

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.60	7.233	7.231	7.229	7.226	7.224	7.222	7.220	7.217	7.215	7.213
1.61	7.210	7.208	7.206	7.204	7.201	7.199	7.197	7.195	7.192	7.190
1.62	7.188	7.185	7.183	7.181	7.179	7.176	7.174	7.172	7.170	7.167
1.63	7.165	7.163	7.161	7.159	7.156	7.154	7.152	7.150	7.147	7.145
1.64	7.143	7.141	7.138	7.136	7.134	7.132	7.129	7.127	7.125	7.123
1.65	7.121	7.118	7.116	7.114	7.112	7.110	7.107	7.105	7.103	7.101
1.66	7.099	7.096	7.094	7.092	7.090	7.088	7.085	7.083	7.081	7.079
1.67	7.077	7.074	7.072	7.070	7.068	7.066	7.063	7.061	7.059	7.057
1.68	7.055	7.053	7.050	7.048	7.046	7.044	7.042	7.040	7.037	7.035
1.69	7.033	7.031	7.029	7.027	7.024	7.022	7.020	7.018	7.016	7.014
1.70	7.011	7.009	7.007	7.005	7.003	7.001	6.999	6.996	6.994	6.992
1.71	6.990	6.988	6.986	6.984	6.982	6.979	6.977	6.975	6.973	6.971
1.72	6.969	6.967	6.965	6.962	6.960	6.958	6.956	6.954	6.952	6.950
1.73	6.948	6.945	6.943	6.941	6.939	6.937	6.935	6.933	6.931	6.929
1.74	6.927	6.924	6.922	6.920	6.918	6.916	6.914	6.912	6.910	6.908
1.75	6.906	6.904	6.901	6.899	6.897	6.895	6.893	6.891	6.889	6.887
1.76	6.885	6.883	6.881	6.879	6.877	6.875	6.872	6.870	6.868	6.866
1.77	6.864	6.862	6.860	6.858	6.856	6.854	6.852	6.850	6.848	6.846
1.78	6.844	6.842	6.840	6.838	6.835	6.833	6.831	6.829	6.827	6.825
1.79	6.823	6.821	6.819	6.817	6.815	6.813	6.811	6.809	6.807	6.805
1.80	6.803	6.801	6.799	6.797	6.795	6.793	6.791	6.789	6.787	6.785
1.81	6.783	6.781	6.779	6.777	6.775	6.773	6.771	6.769	6.767	6.765
1.82	6.763	6.761	6.759	6.757	6.755	6.753	6.751	6.749	6.747	6.745
1.83	6.743	6.741	6.739	6.737	6.735	6.733	6.731	6.729	6.727	6.725
1.84	6.723	6.721	6.719	6.717	6.715	6.713	6.711	6.709	6.707	6.705
1.85	6.703	6.701	6.699	6.697	6.695	6.693	6.692	6.690	6.688	6.686
1.86	6.684	6.682	6.680	6.678	6.676	6.674	6.672	6.670	6.668	6.666
1.87	6.664	6.662	6.660	6.658	6.656	6.655	6.653	6.651	6.649	6.647
1.88	6.645	6.643	6.641	6.639	6.637	6.635	6.633	6.631	6.629	6.628
1.89	6.626	6.624	6.622	6.620	6.618	6.616	6.614	6.612	6.610	6.608
1.90	6.606	6.605	6.603	6.601	6.599	6.597	6.595	6.593	6.591	6.589
1.91	6.587	6.586	6.584	6.582	6.580	6.578	6.576	6.574	6.572	6.570
1.92	6.569	6.567	6.565	6.563	6.561	6.559	6.557	6.555	6.554	6.552
1.93	6.550	6.548	6.546	6.544	6.542	6.540	6.539	6.537	6.535	6.533
1.94	6.531	6.529	6.527	6.525	6.524	6.522	6.520	6.518	6.516	6.514
1.95	6.512	6.511	6.509	6.507	6.505	6.503	6.501	6.500	6.498	6.496
1.96	6.494	6.492	6.490	6.488	6.487	6.485	6.483	6.481	6.479	6.477
1.97	6.476	6.474	6.472	6.470	6.468	6.466	6.465	6.463	6.461	6.459
1.98	6.457	6.455	6.454	6.452	6.450	6.448	6.446	6.445	6.443	6.441
1.99	6.439	6.437	6.436	6.434	6.432	6.430	6.428	6.426	6.425	6.423

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.00	6.421	6.419	6.417	6.416	6.414	6.412	6.410	6.408	6.407	6.405
2.01	6.403	6.401	6.399	6.398	6.396	6.394	6.392	6.391	6.389	6.387
2.02	6.385	6.38[illegible]	6.382	6.380	6.378	6.376	6.375	6.373	6.371	6.369
2.03	6.367	6.366	6.364	6.362	6.360	6.359	6.357	6.355	6.353	6.352
2.04	6.350	6.348	6.346	6.344	6.343	6.341	6.339	6.337	6.336	6.334
2.05	6.332	6.330	6.329	6.327	6.325	6.323	6.322	6.320	6.318	6.316
2.06	6.315	6.313	6.311	6.309	6.308	6.306	6.304	6.303	6.301	6.299
2.07	6.297	6.296	6.294	6.292	6.290	6.289	6.287	6.285	6.283	6.282
2.08	6.280	6.278	6.277	6.275	6.273	6.271	6.270	6.268	6.266	6.265
2.09	6.263	6.261	6.259	6.258	6.256	6.254	6.253	6.251	6.249	6.247
2.10	6.246	6.244	6.242	6.241	6.239	6.237	6.236	6.234	6.232	6.230
2.11	6.229	6.227	6.225	6.224	6.222	6.220	6.219	6.217	6.215	6.213
2.12	6.212	6.210	6.208	6.207	6.205	6.203	6.202	6.200	6.198	6.197
2.13	6.195	6.193	6.192	6.190	6.188	6.187	6.185	6.183	6.182	6.180
2.14	6.178	6.177	6.175	6.173	6.172	6.170	6.168	6.167	6.165	6.163
2.15	6.162	6.160	6.158	6.157	6.155	6.153	6.152	6.150	6.148	6.147
2.16	6.145	6.143	6.142	6.140	6.138	6.137	6.135	6.134	6.132	6.130
2.17	6.129	6.127	6.125	6.124	6.122	6.120	6.119	6.117	6.115	6.114
2.18	6.112	6.111	6.109	6.107	6.106	6.104	6.102	6.101	6.099	6.098
2.19	6.096	6.094	6.093	6.091	6.089	6.088	6.086	6.085	6.083	6.081
2.20	6.080	6.078	6.077	6.075	6.073	6.072	6.070	6.068	6.067	6.065
2.21	6.064	6.062	6.060	6.059	6.057	6.056	6.054	6.052	6.051	6.049
2.22	6.048	6.046	6.044	6.043	6.041	6.040	6.038	6.036	6.035	6.033
2.23	6.032	6.030	6.028	6.027	6.025	6.024	6.022	6.021	6.019	6.017
2.24	6.016	6.014	6.013	6.011	6.009	6.008	6.006	6.005	6.003	6.002
2.25	6.000	5.998	5.997	5.995	5.994	5.992	5.991	5.989	5.987	5.986
2.26	5.984	5.983	5.981	5.980	5.978	5.976	5.975	5.973	5.972	5.970
2.27	5.969	5.967	5.966	5.964	5.962	5.961	5.959	5.958	5.956	5.955
2.28	5.953	5.952	5.950	5.949	5.947	5.945	5.944	5.942	5.941	5.939
2.29	5.938	5.936	5.935	5.933	5.932	5.930	5.928	5.927	5.925	5.924
2.30	5.922	5.921	5.919	5.918	5.916	5.915	5.913	5.912	5.910	5.909
2.31	5.907	5.906	5.904	5.902	5.901	5.899	5.898	5.896	5.895	5.893
2.32	5.892	5.890	5.889	5.887	5.886	5.884	5.883	5.881	5.880	5.878
2.33	5.877	5.875	5.874	5.872	5.871	5.869	5.868	5.866	5.865	5.863
2.34	5.862	5.860	5.859	5.857	5.856	5.854	5.853	5.851	5.850	5.848
2.35	5.847	5.845	5.844	5.842	5.841	5.839	5.838	5.836	5.835	5.833
2.36	5.832	5.830	5.829	5.827	5.826	5.824	5.823	5.821	5.820	5.818
2.37	5.817	5.815	5.814	5.812	5.811	5.810	5.808	5.807	5.805	5.804
2.38	5.802	5.801	5.799	5.798	5.796	5.795	5.793	5.792	5.790	5.789
2.39	5.787	5.786	5.785	5.783	5.782	5.780	5.779	5.777	5.776	5.774

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

CARBON DIOXIDE FROM CO/CO_2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.40	5.773	5.771	5.770	5.769	5.767	5.766	5.764	5.763	5.761	5.760
2.41	5.758	5.757	5.755	5.754	5.753	5.751	5.750	5.748	5.747	5.745
2.42	5.744	5.742	5.741	5.740	5.738	5.737	5.735	5.734	5.732	5.731
2.43	5.729	5.728	5.727	5.725	5.724	5.722	5.721	5.719	5.718	5.717
2.44	5.715	5.714	5.712	5.711	5.709	5.708	5.707	5.705	5.704	5.702
2.45	5.701	5.700	5.698	5.697	5.695	5.694	5.692	5.691	5.690	5.688
2.46	5.687	5.685	5.684	5.683	5.681	5.680	5.678	5.677	5.675	5.674
2.47	5.673	5.671	5.670	5.668	5.667	5.666	5.664	5.663	5.661	5.660
2.48	5.659	5.657	5.656	5.654	5.653	5.652	5.650	5.649	5.647	5.646
2.49	5.645	5.643	5.642	5.640	5.639	5.638	5.636	5.635	5.634	5.632
2.50	5.631	5.629	5.628	5.627	5.625	5.624	5.622	5.621	5.620	5.618
2.51	5.617	5.616	5.614	5.613	5.611	5.610	5.609	5.607	5.606	5.605
2.52	5.603	5.602	5.600	5.599	5.598	5.596	5.595	5.594	5.592	5.591
2.53	5.589	5.588	5.587	5.585	5.584	5.583	5.581	5.580	5.579	5.577
2.54	5.576	5.575	5.573	5.572	5.570	5.569	5.568	5.566	5.565	5.564
2.55	5.562	5.561	5.560	5.558	5.557	5.556	5.554	5.553	5.552	5.550
2.56	5.549	5.547	5.546	5.545	5.543	5.542	5.541	5.539	5.538	5.537
2.57	5.535	5.534	5.533	5.531	5.530	5.529	5.527	5.526	5.525	5.523
2.58	5.522	5.521	5.519	5.518	5.517	5.515	5.514	5.513	5.511	5.510
2.59	5.509	5.507	5.506	5.505	5.503	5.502	5.501	5.499	5.498	5.497
2.60	5.495	5.494	5.493	5.492	5.490	5.489	5.488	5.486	5.485	5.484
2.61	5.482	5.481	5.480	5.478	5.477	5.476	5.474	5.473	5.472	5.471
2.62	5.469	5.468	5.467	5.465	5.464	5.463	5.461	5.460	5.459	5.457
2.63	5.456	5.455	5.454	5.452	5.451	5.450	5.448	5.447	5.446	5.444
2.64	5.443	5.442	5.441	5.439	5.438	5.437	5.435	5.434	5.433	5.432
2.65	5.430	5.429	5.428	5.426	5.425	5.424	5.423	5.421	5.420	5.419
2.66	5.417	5.416	5.415	5.414	5.412	5.411	5.410	5.408	5.407	5.406
2.67	5.405	5.403	5.402	5.401	5.400	5.398	5.397	5.396	5.394	5.393
2.68	5.392	5.391	5.389	5.388	5.387	5.386	5.384	5.383	5.382	5.380
2.69	5.379	5.378	5.377	5.375	5.374	5.373	5.372	5.370	5.369	5.368
2.70	5.367	5.365	5.364	5.363	5.362	5.360	5.359	5.358	5.357	5.355
2.71	5.354	5.353	5.352	5.350	5.349	5.348	5.346	5.345	5.344	5.343
2.72	5.342	5.340	5.339	5.338	5.337	5.335	5.334	5.333	5.332	5.330
2.73	5.329	5.328	5.327	5.325	5.324	5.323	5.322	5.320	5.319	5.318
2.74	5.317	5.315	5.314	5.313	5.312	5.311	5.309	5.308	5.307	5.306
2.75	5.304	5.303	5.302	5.301	5.299	5.298	5.297	5.296	5.295	5.293
2.76	5.292	5.291	5.290	5.288	5.287	5.286	5.285	5.284	5.282	5.281
2.77	5.280	5.279	5.277	5.276	5.275	5.274	5.273	5.271	5.270	5.269
2.78	5.268	5.266	5.265	5.264	5.263	5.262	5.260	5.259	5.258	5.257
2.79	5.256	5.254	5.253	5.252	5.251	5.250	5.248	5.247	5.246	5.245

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.80	5.244	5.242	5.241	5.240	5.239	5.238	5.236	5.235	5.234	5.233
2.81	5.232	5.230	5.229	5.228	5.227	5.226	5.224	5.223	5.222	5.221
2.82	5.220	5.218	5.217	5.216	5.215	5.214	5.212	5.211	5.210	5.209
2.83	5.208	5.207	5.205	5.204	5.203	5.202	5.201	5.199	5.198	5.197
2.84	5.196	5.195	5.194	5.192	5.191	5.190	5.189	5.188	5.186	5.185
2.85	5.184	5.183	5.182	5.181	5.179	5.178	5.177	5.176	5.175	5.174
2.86	5.172	5.171	5.170	5.169	5.168	5.167	5.165	5.164	5.163	5.162
2.87	5.161	5.160	5.158	5.157	5.156	5.155	5.154	5.153	5.151	5.150
2.88	5.149	5.148	5.147	5.146	5.144	5.143	5.142	5.141	5.140	5.139
2.89	5.138	5.136	5.135	5.134	5.133	5.132	5.131	5.129	5.128	5.127
2.90	5.126	5.125	5.124	5.123	5.121	5.120	5.119	5.118	5.117	5.116
2.91	5.115	5.113	5.112	5.111	5.110	5.109	5.108	5.107	5.105	5.104
2.92	5.103	5.102	5.101	5.100	5.099	5.097	5.096	5.095	5.094	5.093
2.93	5.092	5.091	5.090	5.088	5.087	5.086	5.085	5.084	5.083	5.082
2.94	5.081	5.079	5.078	5.077	5.076	5.075	5.074	5.073	5.071	5.070
2.95	5.069	5.068	5.067	5.066	5.065	5.064	5.063	5.061	5.060	5.059
2.96	5.058	5.057	5.056	5.055	5.054	5.052	5.051	5.050	5.049	5.048
2.97	5.047	5.046	5.045	5.044	5.042	5.041	5.040	5.039	5.038	5.037
2.98	5.036	5.035	5.034	5.032	5.031	5.030	5.029	5.028	5.027	5.026
2.99	5.025	5.024	5.023	5.021	5.020	5.019	5.018	5.017	5.016	5.015
3.00	5.014	5.013	5.012	5.010	5.009	5.008	5.007	5.006	5.005	5.004
3.01	5.003	5.002	5.001	4.999	4.998	4.997	4.996	4.995	4.994	4.993
3.02	4.992	4.991	4.990	4.989	4.987	4.986	4.985	4.984	4.983	4.982
3.03	4.981	4.980	4.979	4.978	4.977	4.976	4.974	4.973	4.972	4.971
3.04	4.970	4.969	4.968	4.967	4.966	4.965	4.964	4.963	4.962	4.960
3.05	4.959	4.958	4.957	4.956	4.955	4.954	4.953	4.952	4.951	4.950
3.06	4.949	4.948	4.946	4.945	4.944	4.943	4.942	4.941	4.940	4.939
3.07	4.938	4.937	4.936	4.935	4.934	4.933	4.932	4.930	4.929	4.928
3.08	4.927	4.926	4.925	4.924	4.923	4.922	4.921	4.920	4.919	4.918
3.09	4.917	4.916	4.915	4.914	4.912	4.911	4.910	4.909	4.908	4.907
3.10	4.906	4.905	4.904	4.903	4.902	4.901	4.900	4.899	4.898	4.897
3.11	4.896	4.895	4.894	4.893	4.891	4.890	4.889	4.888	4.887	4.886
3.12	4.885	4.884	4.883	4.882	4.881	4.880	4.879	4.878	4.877	4.876
3.13	4.875	4.874	4.873	4.872	4.871	4.870	4.869	4.868	4.867	4.865
3.14	4.864	4.863	4.862	4.861	4.860	4.859	4.858	4.857	4.856	4.855
3.15	4.854	4.853	4.852	4.851	4.850	4.849	4.848	4.847	4.846	4.845
3.16	4.844	4.843	4.842	4.841	4.840	4.839	4.838	4.837	4.836	4.835
3.17	4.834	4.833	4.832	4.831	4.830	4.828	4.827	4.826	4.825	4.824
3.18	4.823	4.822	4.821	4.820	4.819	4.818	4.817	4.816	4.815	4.814
3.19	4.813	4.812	4.811	4.810	4.809	4.808	4.807	4.806	4.805	4.804

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
3.20	4.803	4.802	4.801	4.800	4.799	4.798	4.797	4.796	4.795	4.794
3.21	4.793	4.792	4.791	4.790	4.789	4.788	4.787	4.786	4.765	4.784
3.22	4.783	4.782	4.781	4.780	4.779	4.778	4.777	4.776	4.775	4.774
3.23	4.773	4.772	4.771	4.770	4.769	4.768	4.767	4.766	4.765	4.764
3.24	4.763	4.762	4.761	4.760	4.759	4.758	4.757	4.756	4.755	4.754
3.25	4.753	4.752	4.751	4.750	4.749	4.748	4.747	4.746	4.745	4.744
3.26	4.743	4.742	4.741	4.740	4.739	4.738	4.737	4.737	4.736	4.735
3.27	4.734	4.733	4.732	4.731	4.730	4.729	4.728	4.727	4.726	4.725
3.28	4.724	4.723	4.722	4.721	4.720	4.719	4.718	4.717	4.716	4.715
3.29	4.714	4.713	4.712	4.711	4.710	4.709	4.708	4.707	4.706	4.705
3.30	4.704	4.703	4.702	4.701	4.701	4.700	4.699	4.698	4.697	4.696
3.31	4.695	4.694	4.693	4.692	4.691	4.690	4.689	4.688	4.687	4.686
3.32	4.685	4.684	4.683	4.682	4.681	4.680	4.679	4.678	4.677	4.676
3.33	4.676	4.675	4.674	4.673	4.672	4.671	4.670	4.669	4.668	4.667
3.34	4.666	4.665	4.664	4.663	4.662	4.661	4.660	4.659	4.658	4.657
3.35	4.656	4.656	4.655	4.654	4.653	4.652	4.651	4.650	4.649	4.648
3.36	4.647	4.646	4.645	4.644	4.643	4.642	4.641	4.640	4.639	4.639
3.37	4.638	4.637	4.636	4.635	4.634	4.633	4.632	4.631	4.630	4.629
3.38	4.628	4.627	4.626	4.625	4.624	4.624	4.623	4.622	4.621	4.620
3.39	4.619	4.618	4.617	4.616	4.615	4.614	4.613	4.612	4.611	4.611
3.40	4.610	4.609	4.608	4.607	4.606	4.605	4.604	4.603	4.602	4.601
3.41	4.600	4.599	4.598	4.598	4.597	4.596	4.595	4.594	4.593	4.592
3.42	4.591	4.590	4.589	4.588	4.587	4.586	4.586	4.585	4.584	4.583
3.43	4.582	4.581	4.580	4.579	4.578	4.577	4.576	4.575	4.575	4.574
3.44	4.573	4.572	4.571	4.570	4.569	4.568	4.567	4.566	4.565	4.565
3.45	4.564	4.563	4.562	4.561	4.560	4.559	4.558	4.557	4.556	4.555
3.46	4.555	4.554	4.553	4.552	4.551	4.550	4.549	4.548	4.547	4.546
3.47	4.545	4.545	4.544	4.543	4.542	4.541	4.540	4.539	4.538	4.537
3.48	4.536	4.536	4.535	4.534	4.533	4.532	4.531	4.530	4.529	4.528
3.49	4.527	4.527	4.526	4.525	4.524	4.523	4.522	4.521	4.520	4.519
3.50	4.519	4.518	4.517	4.516	4.515	4.514	4.513	4.512	4.511	4.510
3.51	4.510	4.509	4.508	4.507	4.506	4.505	4.504	4.503	4.503	4.502
3.52	4.501	4.500	4.499	4.498	4.497	4.496	4.495	4.495	4.494	4.493
3.53	4.492	4.491	4.490	4.489	4.438	4.487	4.487	4.486	4.485	4.484
3.54	4.483	4.482	4.481	4.480	4.480	4.479	4.478	4.477	4.476	4.475
3.55	4.474	4.473	4.473	4.472	4.471	4.470	4.469	4.468	4.467	4.466
3.56	4.466	4.465	4.464	4.463	4.462	4.461	4.460	4.459	4.459	4.458
3.57	4.457	4.456	4.455	4.454	4.453	4.453	4.452	4.451	4.450	4.449
3.58	4.448	4.447	4.446	4.446	4.445	4.444	4.443	4.442	4.441	4.440
3.59	4.440	4.439	4.438	4.437	4.436	4.435	4.434	4.434	4.433	4.432

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

CARBON DIOXIDE FROM CO/CO2 RATIO

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
3.60	4.431	4.430	4.429	4.428	4.428	4.427	4.426	4.425	4.424	4.423
3.61	4.422	4.422	4.421	4.420	4.419	4.418	4.417	4.416	4.416	4.415
3.62	4.414	4.413	4.412	4.411	4.410	4.410	4.409	4.408	4.407	4.406
3.63	4.405	4.405	4.404	4.403	4.402	4.401	4.400	4.399	4.399	4.398
3.64	4.397	4.396	4.395	4.394	4.394	4.393	4.392	4.391	4.390	4.389
3.65	4.388	4.388	4.387	4.386	4.385	4.384	4.383	4.383	4.382	4.381
3.66	4.380	4.379	4.378	4.378	4.377	4.376	4.375	4.374	4.373	4.373
3.67	4.372	4.371	4.370	4.369	4.368	4.368	4.367	4.366	4.365	4.364
3.68	4.363	4.363	4.362	4.361	4.360	4.359	4.358	4.358	4.357	4.356
3.69	4.355	4.354	4.353	4.353	4.352	4.351	4.350	4.349	4.348	4.348
3.70	4.347	4.346	4.345	4.344	4.343	4.343	4.342	4.341	4.340	4.339
3.71	4.339	4.338	4.337	4.336	4.335	4.334	4.334	4.333	4.332	4.331
3.72	4.330	4.330	4.329	4.328	4.327	4.326	4.325	4.325	4.324	4.323
3.73	4.322	4.321	4.321	4.320	4.319	4.318	4.317	4.316	4.316	4.315
3.74	4.314	4.313	4.312	4.312	4.311	4.310	4.309	4.308	4.308	4.307
3.75	4.306	4.305	4.304	4.303	4.303	4.302	4.301	4.300	4.299	4.299
3.76	4.298	4.297	4.296	4.295	4.295	4.294	4.293	4.292	4.291	4.291
3.77	4.290	4.289	4.288	4.287	4.287	4.286	4.285	4.284	4.283	4.283
3.78	4.282	4.281	4.280	4.279	4.278	4.278	4.277	4.276	4.275	4.275
3.79	4.274	4.273	4.272	4.271	4.271	4.270	4.269	4.268	4.267	4.267
3.80	4.266	4.265	4.264	4.263	4.263	4.262	4.261	4.260	4.259	4.259
3.81	4.258	4.257	4.256	4.255	4.255	4.254	4.253	4.252	4.251	4.251
3.82	4.250	4.249	4.248	4.248	4.247	4.246	4.245	4.244	4.244	4.243
3.83	4.242	4.241	4.240	4.240	4.239	4.238	4.237	4.237	4.236	4.235
3.84	4.234	4.233	4.233	4.232	4.231	4.230	4.229	4.229	4.228	4.227
3.85	4.226	4.226	4.225	4.224	4.223	4.222	4.222	4.221	4.220	4.219
3.86	4.219	4.218	4.217	4.216	4.215	4.215	4.214	4.213	4.212	4.212
3.87	4.211	4.210	4.209	4.208	4.208	4.207	4.206	4.205	4.205	4.204
3.88	4.203	4.202	4.201	4.201	4.200	4.199	4.198	4.198	4.197	4.196
3.89	4.195	4.195	4.194	4.193	4.192	4.191	4.191	4.190	4.189	4.188
3.90	4.188	4.187	4.186	4.185	4.185	4.184	4.183	4.182	4.182	4.181
3.91	4.180	4.179	4.178	4.178	4.177	4.176	4.175	4.175	4.174	4.173
3.92	4.172	4.172	4.171	4.170	4.169	4.169	4.168	4.167	4.166	4.166
3.93	4.165	4.164	4.163	4.162	4.162	4.161	4.160	4.159	4.159	4.158
3.94	4.157	4.156	4.156	4.155	4.154	4.153	4.153	4.152	4.151	4.150
3.95	4.150	4.149	4.148	4.147	4.147	4.146	4.145	4.144	4.144	4.143
3.96	4.142	4.141	4.141	4.140	4.139	4.138	4.138	4.137	4.136	4.135
3.97	4.135	4.134	4.133	4.132	4.132	4.131	4.130	4.129	4.129	4.128
3.98	4.127	4.126	4.126	4.125	4.124	4.123	4.123	4.122	4.121	4.121
3.99	4.120	4.119	4.118	4.118	4.117	4.116	4.115	4.115	4.114	4.113

EXHAUST/AIR MOLAR-RATIO FROM A/F RATIO

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
8.0	1.178	1.177	1.177	1.176	1.175	1.174	1.174	1.173	1.172	1.171
8.1	1.171	1.170	1.169	1.168	1.168	1.167	1.166	1.166	1.165	1.164
8.2	1.163	1.163	1.162	1.161	1.161	1.160	1.159	1.158	1.158	1.157
8.3	1.156	1.156	1.155	1.154	1.154	1.153	1.152	1.151	1.151	1.150
8.4	1.149	1.149	1.148	1.147	1.147	1.146	1.145	1.145	1.144	1.143
8.5	1.143	1.142	1.141	1.141	1.140	1.139	1.139	1.138	1.137	1.137
8.6	1.136	1.135	1.135	1.134	1.133	1.133	1.132	1.132	1.131	1.130
8.7	1.130	1.129	1.128	1.128	1.127	1.126	1.126	1.125	1.125	1.124
8.8	1.123	1.123	1.122	1.121	1.121	1.120	1.120	1.119	1.118	1.118
8.9	1.117	1.117	1.116	1.115	1.115	1.114	1.114	1.113	1.112	1.112
9.0	1.111	1.111	1.110	1.109	1.109	1.108	1.108	1.107	1.106	1.106
9.1	1.105	1.105	1.104	1.104	1.103	1.102	1.102	1.101	1.101	1.100
9.2	1.100	1.099	1.098	1.098	1.097	1.097	1.096	1.096	1.095	1.094
9.3	1.094	1.093	1.093	1.092	1.092	1.091	1.091	1.090	1.090	1.089
9.4	1.088	1.088	1.087	1.087	1.086	1.086	1.085	1.085	1.084	1.084
9.5	1.083	1.083	1.082	1.082	1.081	1.081	1.080	1.080	1.079	1.078
9.6	1.078	1.077	1.077	1.076	1.076	1.075	1.075	1.074	1.074	1.073
9.7	1.073	1.072	1.072	1.071	1.071	1.070	1.070	1.069	1.069	1.068
9.8	1.068	1.067	1.067	1.067	1.066	1.066	1.065	1.065	1.064	1.064
9.9	1.063	1.063	1.062	1.062	1.061	1.061	1.060	1.060	1.059	1.059
10.0	1.058	1.058	1.058	1.057	1.057	1.056	1.056	1.055	1.055	1.054
10.1	1.054	1.053	1.053	1.053	1.052	1.052	1.051	1.051	1.050	1.050
10.2	1.049	1.049	1.049	1.048	1.048	1.047	1.047	1.046	1.046	1.046
10.3	1.045	1.045	1.044	1.044	1.043	1.043	1.043	1.042	1.042	1.041
10.4	1.041	1.040	1.040	1.040	1.039	1.039	1.038	1.038	1.038	1.037
10.5	1.037	1.036	1.036	1.036	1.035	1.035	1.034	1.034	1.034	1.033
10.6	1.033	1.032	1.032	1.032	1.031	1.031	1.030	1.030	1.030	1.029
10.7	1.029	1.028	1.028	1.028	1.027	1.027	1.027	1.026	1.026	1.025
10.8	1.025	1.025	1.024	1.024	1.024	1.023	1.023	1.022	1.022	1.022
10.9	1.021	1.021	1.021	1.020	1.020	1.019	1.019	1.019	1.018	1.018
11.0	1.018	1.017	1.017	1.017	1.016	1.016	1.016	1.015	1.015	1.015
11.1	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.012	1.011	1.011
11.2	1.011	1.010	1.010	1.010	1.009	1.009	1.0[illegible]9	1.008	1.008	1.008
11.3	1.007	1.007	1.007	1.006	1.006	1.006	1.005	1.005	1.005	1.004
11.4	1.004	1.004	1.004	1.003	1.003	1.003	1.002	1.002	1.002	1.001
11.5	1.001	1.001	1.000	1.000	1.000	.999	.999	.999	.999	.998
11.6	.998	.998	.997	.997	.997	.996	.996	.996	.996	.995
11.7	.995	.995	.994	.994	.994	.993	.993	.993	.993	.992
11.8	.992	.992	.991	.991	.991	.991	.990	.990	.990	.989
11.9	.989	.989	.989	.988	.988	.988	.987	.987	.987	.987

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

EXHAUST/AIR MOLAR-RATIO FROM A/F RATIO

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
12.0	.986	.986	.986	.986	.985	.985	.985	.984	.984	.984
12.1	.984	.983	.983	.983	.983	.982	.982	.982	.982	.981
12.2	.981	.981	.981	.980	.980	.980	.980	.979	.979	.979
12.3	.978	.978	.978	.978	.977	.977	.977	.977	.976	.976
12.4	.976	.976	.976	.975	.975	.975	.975	.974	.974	.974
12.5	.974	.973	.973	.973	.973	.972	.972	.972	.972	.971
12.6	.971	.971	.971	.970	.970	.970	.970	.970	.969	.969
12.7	.969	.969	.968	.968	.968	.968	.967	.967	.967	.967
12.8	.967	.966	.966	.966	.966	.965	.965	.965	.965	.965
12.9	.964	.964	.964	.964	.963	.963	.963	.963	.963	.962
13.0	.962	.962	.962	.962	.961	.961	.961	.961	.960	.960
13.1	.960	.960	.960	.959	.959	.959	.959	.959	.958	.958
13.2	.958	.958	.958	.957	.957	.957	.957	.957	.956	.956
13.3	.956	.956	.956	.955	.955	.955	.955	.955	.954	.954
13.4	.954	.954	.954	.953	.953	.953	.953	.953	.952	.952
13.5	.952	.952	.952	.951	.951	.951	.951	.951	.950	.950
13.6	.950	.950	.950	.950	.949	.949	.949	.949	.949	.948
13.7	.948	.948	.948	.948	.947	.947	.947	.947	.947	.947
13.8	.946	.946	.946	.946	.946	.945	.945	.945	.945	.945
13.9	.945	.944	.944	.944	.944	.944	.943	.943	.943	.943
14.0	.943	.943	.942	.942	.942	.942	.942	.941	.941	.941
14.1	.941	.941	.941	.940	.940	.940	.940	.940	.940	.939
14.2	.939	.939	[illegible]	.939	.939	.938	.938	.938	.938	.938
14.3	.937	.937	.937	.937	.937	.937	.936	.936	.936	.936
14.4	.936	.936	.935	.935	.935	.935	.935	.935	.934	.934
14.5	.934	.934	.934	.934	.933	.933	.933	.933	.933	.933
14.6	.932	.932	.932	.932	.932	.932	.932	.932	.932	.932
14.7	.932	.932	.933	.933	.933	.933	.933	.933	.933	.933
14.8	.933	.933	.933	.933	.933	.933	.933	.933	.933	.933
14.9	.933	.933	.933	.933	.933	.933	.933	.933	.933	.933
15.0	.933	.933	.933	.933	.933	.933	.933	.933	.933	.933
15.1	.933	.933	.933	.933	.933	.933	.933	.933	.933	.933
15.2	.933	.933	.933	.933	.933	.933	.933	.933	.933	.933
15.3	.933	.934	.934	.934	.934	.934	.934	.934	.934	.934
15.4	.934	.934	.934	.934	.934	.934	.934	.934	.934	.934
15.5	.934	.934	.934	.934	.934	.934	.934	.934	.934	.934
15.6	.934	.934	.934	.934	.934	.934	.934	.934	.934	.934
15.7	.934	.934	.934	.934	.934	.934	.935	.935	.935	.935
15.8	.935	.935	.935	.935	.935	.935	.935	.935	.935	.935
15.9	.935	.935	.935	.935	.935	.935	.935	.935	.935	.935

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

EXHAUST/AIR MOLAR-RATIO FROM A/F RATIO

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
16.0	.935	.935	.935	.935	.935	.935	.935	.935	.935	.935
16.1	.935	.935	.935	.935	.936	.936	.936	.936	.936	.936
16.2	.936	.936	.936	.936	.936	.936	.936	.936	.936	.936
16.3	.936	.936	.936	.936	.936	.936	.936	.936	.936	.936
16.4	.936	.936	.936	.936	.936	.936	.936	.936	.937	.937
16.5	.937	.937	.937	.937	.937	.937	.937	.937	.937	.937
16.6	.937	.937	.937	.937	.937	.937	.937	.937	.937	.937
16.7	.937	.937	.937	.937	.937	.937	.937	.937	.938	.938
16.8	.938	.938	.938	.938	.938	.938	.938	.938	.938	.938
16.9	.938	.938	.938	.938	.938	.938	.938	.938	.938	.938
17.0	.938	.938	.938	.938	.938	.938	.939	.939	.939	.939
17.1	.939	.939	.939	.939	.939	.939	.939	.939	.939	.939
17.2	.939	.939	.939	.939	.939	.939	.939	.939	.939	.939
17.3	.939	.940	.940	.940	.940	.940	.940	.940	.940	.940
17.4	.940	.940	.940	.940	.940	.940	.940	.940	.940	.940
17.5	.940	.940	.940	.940	.940	.940	.941	.941	.941	.941
17.6	.941	.941	.941	.941	.941	.941	.941	.941	.941	.941
17.7	.941	.941	.941	.941	.941	.941	.941	.941	.941	.942
17.8	.942	.942	.942	.942	.942	.942	.942	.942	.942	.942
17.9	.942	.942	.942	.942	.942	.942	.942	.942	.942	.942
18.0	.943	.943	.943	.943	.943	.943	.943	.943	.943	.943
18.1	.943	.943	.943	.943	.943	.943	.943	.943	.943	.943
18.2	.943	.944	.944	.944	.944	.944	.944	.944	.944	.944
18.3	.944	.944	.944	.944	.944	.944	.944	.944	.944	.944
18.4	.944	.945	.945	.945	.945	.945	.945	.945	.945	.945
18.5	.945	.945	.945	.945	.945	.945	.945	.945	.945	.945
18.6	.945	.946	.946	.946	.946	.946	.946	.946	.946	.946
18.7	.946	.946	.946	.946	.946	.946	.946	.946	.946	.947
18.8	.947	.947	.947	.947	.947	.947	.947	.947	.947	.947
18.9	.947	.947	.947	.947	.947	.947	.947	.948	.948	.948

CORRECTION FACTOR FOR GAS VOLUMES TO 68 F

	.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
-50.0	1.577	1.584	1.591	1.598	1.605	1.612	1.619	1.626	1.634	1.641
-40.0	1.510	1.516	1.523	1.529	1.536	1.543	1.549	1.556	1.563	1.570
-30.0	1.447	1.453	1.459	1.465	1.472	1.478	1.484	1.490	1.497	1.503
-20.0	1.388	1.394	1.400	1.406	1.411	1.417	1.423	1.429	1.435	1.441
-10.0	1.333	1.339	1.344	1.350	1.355	1.360	1.366	1.372	1.377	1.383
-.0	1.282	1.287	1.292	1.297	1.302	1.307	1.312	1.318	1.323	1.328
.0	1.282	1.277	1.272	1.267	1.262	1.257	1.252	1.247	1.243	1.238
10.0	1.233	1.228	1.224	1.219	1.214	1.210	1.205	1.201	1.196	1.192
20.0	1.187	1.183	1.178	1.174	1.170	1.165	1.161	1.157	1.152	1.148
30.0	1.144	1.140	1.136	1.131	1.127	1.123	1.119	1.115	1.111	1.107
40.0	1.103	1.099	1.095	1.091	1.087	1.083	1.080	1.076	1.072	1.068
50.0	1.064	1.061	1.057	1.053	1.050	1.046	1.042	1.039	1.035	1.031
60.0	1.028	1.024	1.021	1.017	1.014	1.010	1.007	1.003	1.000	.997
70.0	.993	.990	.987	.983	.980	.977	.973	.970	.967	.964
80.0	.960	.957	.954	.951	.948	.945	.941	.938	.935	.932
90.0	.929	.926	.923	.920	.917	.914	.911	.908	.905	.902
100.0	.900	.897	.894	.891	.888	.885	.882	.880	.877	.874
110.0	.871	.869	.866	.863	.860	.858	.855	.852	.850	.847
120.0	.844	.842	.839	.837	.834	.831	.829	.826	.824	.821
130.0	.819	.816	.814	.811	.809	.807	.804	.802	.799	.797
140.0	.794	.792	.790	.787	.785	.783	.780	.778	.776	.773
150.0	.771	.769	.767	.764	.762	.760	.758	.755	.753	.751
160.0	.749	.747	.745	.742	.740	.738	.736	.734	.732	.730
170.0	.728	.726	.724	.721	.719	.717	.715	.713	.711	.709
180.0	.707	.705	.703	.701	.699	.697	.696	.694	.692	.690
190.0	.688	.686	.684	.682	.680	.678	.677	.675	.673	.671
200.0	.669	.667	.666	.664	.662	.660	.658	.657	.655	.653
210.0	.651	.650	.648	.646	.644	.643	.641	.639	.638	.636
220.0	.634	.633	.631	.629	.628	.626	.624	.623	.621	.619

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

VAPOR PRESSURE OF WATER, IN. HG AT DEG. F

	.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.0	.045	.047	.049	.051	.054	.056	.059	.062	.065	.068
10.0	.071	.074	.077	.081	.084	.088	.092	.096	.100	.105
20.0	.109	.114	.119	.124	.130	.135	.141	.147	.153	.160
30.0	.166	.173	.180	.188	.195	.203	.212	.220	.229	.238
40.0	.248	.258	.268	.278	.289	.300	.312	.324	.336	.349
50.0	.363	.376	.390	.405	.420	.436	.452	.469	.486	.503
60.0	.522	.541	.560	.580	.601	.622	.644	.667	.690	.715
70.0	.739	.765	.791	.818	.846	.875	.905	.935	.967	.999
80.0	1.032	1.067	1.102	1.138	1.175	1.214	1.253	1.293	1.335	1.378
90.0	1.422	1.467	1.513	1.561	1.610	1.660	1.712	1.765	1.820	1.876
100.0	1.933	1.992	2.053	2.115	2.178	2.244	2.311	2.379	2.450	2.522
110.0	2.596	2.673	2.750	2.830	2.912	2.996	3.082	3.170	3.261	3.353
120.0	3.448	3.545	3.644	3.746	3.850	3.957	4.066	4.178	4.292	4.409

ETHYL CORPORATION, DETROIT, MARCH 1, 1966

APPENDIX IV. RUNNING THE DATA

This appendix is a series of instructions for running the car exhaust surveillance data on the Ethyl Corporation IBM 1620 Model II Digital Computer. This computer has a 60-K decimal digit memory core, automatic division, and indirect addressing.

The two programs TRAILR and CITABL are available as complete program deck packages ready to load. The starting address is 00946.

EDITING RAW DATA DECK

1. The "raw data deck" is the deck of punched cards received from the key puncher. It can be edited in whole or part.

2. Sort the portion of the deck being edited as follows: Col. 80, 79, 78, 77, 76, 75, 74, 73, 72, 71. Note the permissible slots as the sort proceeds (Table 5). Take out any exceptions and examine the cards. Correct and put in order.

3. List the sorted "raw data deck" double-spaced.

4. Load program TRAILR. Put Switch 1 ON for EDIT MODE and Switch 2 ON for the first run through. Load the data deck. The typewriter will show the run number. Variables out of range are listed. Refer to the computer program listing for the identification. Some errors of omission can be corrected arbitrarily. Ambient barometric pressure, temperature and humidity can usually be supplied from a companion run on the same day. A missing odometer reading can be estimated from the other repeat run on the same vehicle. A gross error, or a very wrong integrator calibration, can usually be supplied. The deck cards should be fed in about 30 cards at a time since the message

I/O ER 3
SKIP

will lead to a blind reading of all of the cards in the input hopper. If this happens, press INSTANT STOP and RESET and branch back to the beginning by pressing INSERT and typing

4900946 R/S.

Reload starting at the first card of the next run following the bad one. Examine the listing for a gross input error.

5. If Switch 2 is OFF the computer halts permitting a reload of a run with an error. Press START.

6. Not all errors may be detected in the first pass. After correction of the first batch, repeat the editing process. Eventually all obvious errors can be picked up.

7. There still may be less obvious errors which will not show up until the comparison tables are made using the CITABL program.

RUN SUMMARY TABLES

1. The Run Summary Tables are prepared using the TRAILR program with Switch 1 OFF and Switch 3 OFF. The input is the edited raw data deck, which need not include all runs.

2. Load program TRAILR. Put Switch 1 OFF, Switch 2 ON, Switch 3 OFF. Load data deck. The output is about 7000 cards for a full set of runs for a visit to a city; roughly 57 cards per run.

3. List these with format control. Save the deck, labeling it with the VISIT-CITY code. Mark it RUN SUMMARIES.

REFURBISHED DATA DECK AND STATISTICAL ANALYSIS DECK

1. Cards for the Refurbished Data Deck and the Statistical Analysis Deck have already been generated in the Run Summary preparation. They can be sorted out on Col. 79; the Refurbished Data Deck falls in Slot 0, the Statistical Analysis Deck in Slot 3, and the Run Summary cards in the reject slot. It is desirable, for record purposes, to keep the Run Summary output material together. A fresh run with Switch 3 ON bypasses the Run Summary card output.

2. Load program TRAILR. Put Switch 1 OFF, Switch 2 ON, and Switch 3 ON. Load the same edited data deck used above. The output is about 18 cards per run.

3. Sort the output on Col. 79. Discard rejects. Slot 0 has Refurbished Data Deck. Slot 3 has Statistical Analysis Deck.

4. Save these until all the runs for a visit to a city have been processed. At that time, sort the Refurbished Data Deck on Col. 80, 78, 77, 76, 73, 74. It is possible that two runs have the same code number by accident. If time permits, run this sorted Refurbished Data Deck using TRAILR in EDIT MODE, that is, Switch 1 ON, Switch 2 ON.

COMPARISON TABLES - EFFLUENT VARIABLES

1. The Variable Comparison Tables[a] are prepared using Program CITABL using a complete set of runs for a visit to a city. The input is the Refurbished Data Deck.

2. Sort the Refurbished Data Deck on Col. 80, 78, 77, 76, 73, 74.

a. These tables are often termed Table 2 as in the original contract.

3. Load Program CITABL. Put Switch 1 ON to skip typing of run numbers if desired. Load data deck. The deck will read in until near the end when output punching will start. (The balance of the cards are for runs with Ethyl Corp. Plymouths. Run these cards out, since they are not needed. Messages will be typed at load time indicating runs on Ethyl cars which are skipped.)

COMPARISON TABLES - ALL VARIABLES

1. Comparison tables for all variables including those not considered in the previous section can be obtained using the following procedure.

2. Two passes are needed. The "pass" cards described below are loaded first, then the data deck.

3. The Pass 1 card has the following numbers if I3 format across the card:

1 20 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

The Pass 2 card has similarly

2 9 4 5 7 8 9 10 11 12 13

(The first integer indicates the pass, the second the number of variables in the output list which follows. The numbers in the list are variable storage numbers defined in a later section.)

4. Load Program CITABL, the Pass 1 Card, and the Refurbished Data Deck. As soon as the punch starts remove the balance of the data deck (use non-process run out) and reload with the Pass 2 Card now in front instead of the Pass 1 Card. The Pass 2 input will start as soon as the punching of Pass 1 is completed.

5. In order to obtain comparison tables for part of the variables repeat the above procedure using a Pass card containing the required information in I3 format:

Col. 3	Pass No.
Col. 5, 6	Number of variable comparisons to be punched out in this pass.
Col. 8, 9, etc.	Variable storage numbers of variables to be processed in this pass.

The storage number for each variable is shown in Table 6. For example, to make comparison tables for A/F ratio (Pass 1, Storage No. 5), CO/CO_2 scaled HC-FID, ppmc (Pass 1, Storage No. 10), N_2 scaled HC-FID, ppmc (Pass 2, Storage No. 10), and CO/CO_2 scaled HC-FID, lb/mile (Pass 1, Storage No. 17).

The following cards for Pass 1 and 2 respectively are needed:

1 3 5 10 17

2 1 10

TABLE 5. PERMISSIBLE CODE VALUES

Column	Information	Permissible values
80	Serial card number	0 to 9
79	Card set number	0
78	Repeat run	1, 2
76, 77	Car number	
77	Units	0 to 9
76	Tens	1, 9
75	Sampler number	1 to 9
74	Car make	1, 2, 3
73	Device	1, 2
72	Visit	1, 2, 3, 4
71	City	1, 2, 3, 4, 5

TABLE 6. NUMBERING OF VARIABLES FOR COMPARISON TABLE MAKER IBM 1620 PROGRAM CITABL

	Pass 1		Pass 2	
Storage Number	Variable Number	Variable Name	Variable Number	Variable Name
1	1	Serial run no.	1	Serial run no.
2	2	Odometer	2	Odometer
3	3	Miles/hour	3	Miles/hour
4	4	N_2 dilution ratio	23	Ambient air temp.
5	5	A/F ratio	24	Ambient local bar. pr.
6	6	SCF air/mile	25	(Open)
7	7	SCF exh/mile	26	Per cent air
15	15	Carburetor temp.	15	Carburetor temp.
		CO/CO_2 scaled data		N_2 scaled data
8	8	Miles/gal	27	Miles/gal
9	9	HC-IR, ppmc	28	HC-IR, ppmc
10	10	HC-FID ppmc	29	HC-FID, ppmc
11	11	CO, per cent	30	CO, per cent
12	12	CO_2, per cent	31	CO_2, per cent
13	13	NOx, ppm	32	NOx, ppm
		N_2 scaled data		N_2 scaled data
16	16	HC-IR, lb/mile	16	HC-IR, lb/mile
17	17	HC-FID, lb/mile	17	HC-FID, lb/mile
18	18	CO, lb/mile	18	CO, lb/mile
19	19	CO_2, lb/mile	19	CO_2, lb/mile
20	20	NOx, lb/mile	20	NOx lb/mile
14	14	O_2, per cent	33	O_2, per cent

During Pass 1, all variables shown in that column are stored and given the storage numbers shown at the left. Similarly for Pass 2. Note that nine variables are stored in both Pass 1 and Pass 2.